MISCELLANEOUS OBSERVATIONS,

ETC., ETC.

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MISCELLANEOUS OBSERVATIONS

CONNECTED WITH

THE PHYSICAL SCIENCES.

BY

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INTRODUCTORY REMARKS BY THE TRANSLATOR.

THE *Miscellanea Observata,* of which a complete translation is now for the first time submitted to the English reader, was published at Leipsic in 1722, in three Parts, to which a Fourth Part, published in the same year at Schiffbeck near Hamburgh, was subsequently added. Owing probably to its small size, and separate publication, the Fourth Part has become exceedingly scarce, and indeed it is a matter of congratulation that even a single copy could be procured for the completion of the present work.

The *Miscellanea Observata* were noticed in the *Acta Literaria Sveciæ,* 1722, and reviewed at greater length in the *Acta Eruditorum Lipsiensia* for May, 1723, p. 263, and June of the same year, p. 96. An able translation of the sexagenary calculus* appeared in the *Gentleman's Magazine* for September, 1754; pp. 423, 424, and two of the original papers in the Appendix were translated in the *Acta Germanica,* London, 1742.

These are the chief periodicals in which the *Miscellanea Observata* have been noticed, for we are compelled to pass over the *Historie der Gelehrsamkeit* (History of Learning), which appears also to have reviewed them, as it has shared the same fate as its anonymous composers, and has departed from the memory of men. This review appears to have been actuated

* This new calculus is mentioned at greater length in a letter to the Rev. Dr. Nordberg, which is given in the appendix to his "History of Charles XII." A translation of the French abridgment of the original letter may be seen in the *Intellectual Repository,* May, 1842, pp. 161—165.

by a minute spirit of criticism, which is not entirely lost at the present day, and to have taken more notice of the typographical errors, than of the views set forth in the essays. It must, however, in candour be acknowledged, that there was no scarcity of errata; for at the head of a long list of alterations and omissions there is a notice to the reader, that "as innumerable typographical errors have crept in, owing to the negligence of the person appointed to revise the press, the volume scarcely admits of correction; the reader would therefore do well in throwing it aside, as a revised edition would shortly be published."* This second edition probably never appeared.

Let us, however, pass from the errata, which affect the sense materially in but very few instances. The work embraces a great variety of subjects, geological, scientific, mathematical, and mechanical, together with several suggestions for improvements in different branches of the arts. In all these papers, the acute observation and practical sagacity of the author are conspicuous; and if a few of his deductions may be considered as somewhat questionable, others have since been corroborated by modern researches.

But it is not only in a scientific point of view that these papers are interesting. Although many of the theories are highly ingenious, and carefully supported by experiments and observations, as accurately performed as the state of science at that time allowed, they will be considered by some readers as chiefly valuable in shewing the extraordinary industry and abilities of the author at a comparatively early period of his life. As an additional proof of the extent and versatility of his powers, we shall subjoin a brief account of the several works and treatises mentioned in the *Acta Literaria Sveciæ*, vol. i., extending from the year 1720 to 1724.

1. (page 5.) Om Wattnens Hoegd, och foerra Werldens starka Ebb och Flod, Bewis utur Swerige. Stockholm, 1719, 8vo., pp. 40.

Arguments derived from appearances in Sweden in favour

* "Errata typographica, quia innumera, negligentiâ correctoris irrepserant, vix emendare vacat: quorum ob causam impressionem hanc rejicere debet Lector, aliam emendatiorem propediem habiturus."

of the depth of the waters and greater tides of the sea in the ancient world.

2. (page 22.) De Monetarum Mensurarumque Ordinatione Decimali.

On the Decimal System of Monies and Measures, to facilitate calculation, and abolish fractions. This work was published in Swedish with the following title, "Fôrslag till vârt Mynts och Mâls Indelning." Upsala, 1719, 4to. In the Catalogue of the Upsala Library, another edition of this work in octovo, 1795, is mentioned.

3. (page 26.) De Terræ Planetarumque Motu atque statione. Skara, 1719, 8vo.

On the Motion and Position of the Earth and Planets.

This treatise was published in Swedish, under the title, "Om Jordenes och Planeternas Gâng och Stând."

4. Dædalus Hyperboreus, sive nova Experimenta Mathematica et Physica. Upsaliæ, 1716, 1717, 1718. 4to.

This work, consisting of new experiments in mathematics and physics, by Swedenborg and several of his scientific friends, was published in six parts, all of which are in Swedish, but the fifth part has a Latin version also.

5. (page 27.) Foersoek, att finna Oestra och Westra Længden igen, igenom Mânan. Upsala, 1718, 8vo., pp. 38.

Attempts to find the Longitude of Places by Lunar Observations.

This is the original Swedish edition of the work subsequently published in Latin at Amsterdam in 1721, and of which a translation has been given in the *Principles of Chemistry, with other Treatises.*

6. (p. 111.) Om Vennerns fallande och stigande.

On the rise and fall of Lake Wenner, with an accurate sketch of the cataracts of the river Gotha Elf.

This is a manuscript dissertation of Swedenborg's, founded on various observations transmitted to him in letters by scientific persons. The article in the *Acta Literaria* does not mention whether it was ever printed, nor is the size of the dissertation stated. Reference is made however to page 79, and the review would lead us to suppose that the original treatise was a very interesting work.

7. (page 126.) Regel-Konsten författad i Tijo Bökker, &c. Upsala, 1718, 8vo., pp. 135.

Algebra, or the Art of Rules, comprised in ten books, &c.

This work is reviewed at considerable length, and is mentioned with great honour—not only because the author was the first Swede who wrote on the higher branches of the subject, but for the excellence of the treatise itself, the clearness of the language, and the examples shewing the application and uses of the rules. Each book is divided into three parts. The following is a very brief outline of the contents of this work.

Book I. contains the definitions and explanations of the terms employed, and the simpler arithmetical processes.

—— II. The mechanical powers, the lever, pulley, inclined plane, &c., with a variety of problems.

—— III. The laws of proportions and ratios; also with numerous problems.

—— IV. Geometrical theorems, stereometry, and specific gravity.

—— V. The properties of the Parabola and Hyperbola.

—— VI. The properties of the Parabola more fully considered, with numerous other problems.

—— VII. On the theory of Projectiles and Artillery, with many problems.

—— VIII. }
—— IX. } On adfected Roots, and on the integral and differential Calculus.
—— X. }

8. (page 192.) A letter (on the Primeval Ocean) to Jacob a Melle.

9. (page 209.) An announcement of the treatises comprised in the volume of *Chemical Specimens*.

10. (page 282.) Novæ Regulæ de Caloris conservatione in Conclavibus.

New Rules for maintaining Heat in Rooms.

11. (page 302.) A notice of the publication of the treatises mentioned at p. 209, and also of the first Three Parts of the *Miscellanea Observata*.

12. (page 353.) Expositio Legis Hydrostaticæ, quâ demonstrari potest effectus et vis aquæ diluvianæ altissimæ in saxa et materias fundi sui.

An Elucidation of a Law of Hydrostatics, demonstrating the power of the deepest waters of the Deluge, and their action on the Rocks and other Substances at the bottom of their Bed.

13. (page 366.) Another notice of the treatises mentioned at p. 209, and of the *Miscellanea Observata,* including the Fourth Part.

14. (page 588.) Camena Borea cum Heroum et Heroidum factis ludens; sive Fabellæ, Ovidianis similes, sub variis nominibus scriptæ ab E. S. Sveco. Gryphiswaldiæ, literis Dan. Ben. Starckii. 1715. 8vo.

15. (page 589.) Fabula de Amore et Metamorphosi Uranies in Virum et in famulum Apollinis; ad illustrisimum et excellentissimum R. S. Senatorem, comitem Mauritium Wellink. Naupotami, typis Herm. Henr. Hollii, 1722. 4to. carmine elegiaco.

Of the above, three are original papers by Swedenborg; and as they are of the same character as the *Miscellaneous Observations,* it has been deemed advisable to add them in the form of an Appendix.

Considerable difficulty has been experienced in translating the various terms employed in the papers on geological subjects. Owing to the numerous distinctions introduced by the researches of modern geologists, many of the old expressions are no longer in use, and others have been considerably modified in their significations. In the infancy of the science, the same terms were much more comprehensive in their application than at present: for instance, all rocks consisting of small grains, were formerly included under the name of granite, a term first used by the Italian geologists, and literally signifying *grained* [*granito*]. Rocks of very different natures were thus classed together; but as science advanced, distinctions were gradually introduced, which render the observations of the earlier geologists no longer exact in modern phraseology. Cronstedt, who wrote in 1758, says that granite occurs on the summit of the Kinnekulla; but Sir Roderick Murchison has lately ascertained that it consists, in fact, of eruptive trap. This difference is owing to the greater precision which has been observed in the respective terms: in Engeström's translation of Cronstedt's

"System of Mineralogy," London, 1772, the Swedish *gråsten* is rendered granite: and Wallerius, in his "Systema Mineralogicum," 8vo., Vindobonæ, 1778, (vol. i., p. 421—441,) describes no less than five distinct kinds of rocks, comprising fifty or sixty varieties, all of which are included under the Swedish term *gråsten*, or *gråberg*, although their composition is widely different. The *saxum griseum* (*gråsten*) of our author, will therefore require rather an extensive application; but may generally be considered as representing the various rocks from the granitic to the trapean formations; amongst the latter of which the modern *graustein* is classed by Werner. The *graustein*, however, is not very accurately defined, even at present; according to Brochant, it is composed of very small grains of white feldspar and black amphibole, whilst Heidinger and Blumenbach consider it as an argillaceous porphyry. Several of these rocks occur in strata, and formations of stratified granite have been discovered, of which De la Beche mentions an example at Weinböhla, as existing above chalk; which might be adduced in support of its aqueous origin.

We may perhaps be allowed to give a short account of the ætites, belemnites, boles, and entrochi, all of which terms occur in these *Miscellaneous Observations*.

Ætites, or eagle stones, (from ἀετὸς, an eagle,) were so called, because they were supposed to be found in eagle's nests. They are hollow stones, containing a nucleus, which rattles on being shaken, like a nut in its shell. They were formerly considered to possess several extraordinary medicinal, and even magical powers.

Belemnite, or thunder-stone, (from βέλος, a dart,) is a fossil of an extinct order of Cephalopoda, occurring amongst marine remains in marble, limestone, and chalk. Its form is cylindric, or rather it is part of a very acute angled cone. When exposed to a red heat, it emits an odour like that of burnt horn, which led some of the ancients to imagine it to be one of the materials of the thunderbolt. Others, however, believed that it was of animal origin, and that it was produced by the lynx; it was, therefore, occasionally called the lynx-stone.

Boles were of different kinds; the most important was the

Armenian bole, a hard and compact earth, of a bright red colour, somewhat inclining to yellow. It was employed in distilling sea salt and nitre; in which operation, the sulphuric acid it contains acted on the alkaline bases of those salts, and liberated their acids. Other kinds of boles were neutral, or alkaline, and were used as colouring matters.

Entrochi are the fossil remains of some extinct marine animal of the asteriæ kind, probably the petrified arms of the sea star fish, (stella arborescens.) They are generally cylindric columns, about an inch in length, consisting of a number of small joints, like so many segments of a cylinder. The entrochus pyramidalis is a common fossil in Sweden.

The papers on the Elementary and Bullular Hypotheses are evidently the first ideas of the theories afterwards so ably developed in the *Principia,** to which the reader is referred for additional confirmation. The *Principles of Chemistry*† likewise throw considerable light on several of the subjects treated of in these pages; and in their turn, they also derive support from the theories and experiments in these *Miscellaneous Observations.* So true it is, that the same idea of thought runs through the whole of the author's philosophical writings, susceptible of amplification and expansion; so that as our facts increase, they may each be arranged in their proper place and order; of which, indeed, several recent discoveries in the higher departments of science are remarkable illustrations.

The question has been asked, but chiefly by those who are unacquainted with any of the writings of Swedenborg, What is the object of publishing works on science which have been so long buried in the dust? Is any benefit to be expected from reviving them? To this we may reply, that the first and principal object is, to obtain a complete edition of all the works of Swedenborg, that by his own merits he may be judged, and either fall or stand, according to the result of the investi-

* *The Principia; or, the First Principles of Natural Things, being New Attempts toward a Philosophical Explanation of the Elementary World; by Emanuel Swedenborg.* Translated from the Latin, by the Rev. A. Clissold, M.A.

† *Some Specimens of a Work on the Principles of Chemistry, with other Treatises, by Emanuel Swedenborg.* Translated from the Latin, by Charles Edward Strutt.

gation. The case is similar to that of the works of Lord Bacon, of which complete editions have been published, (notwithstanding that some of the views advanced are far more open to the charge of error than any in our author's pages,) in order that a correct idea may be formed of his extraordinary powers, and the general tendency of his philosophy; as it is justly considered, that the errors and mistakes into which he may have fallen, are not to be weighed against the solid gold which shines throughout his works. Such also is the opinion which should, and in due time will, be formed of the writings of Swedenborg, and of the character of their author.

A second reason for publishing the scientific works, is, that they are essentially different in kind from those of the present day. The views they advance are exceedingly suggestive, and appear capable of uniting all the sciences into one harmonious whole. Although at present only a few points are indicated in the great circle, enough has been done to trace the outline; and it is to be hoped that ere long, the labours of a new science may complete its beautiful proportions.

On these subjects, however, this is not the place to enter; and therefore, it only remains respectfully to submit this volume to the consideration of the numerous and rapidly increasing readers of these works, both in this country and in America.

London, June 1st, 1847.

To the most noble COUNT GUSTAVUS BONDE, *President of the Royal Metallic College of Sweden.*

MANY reasons induce me, most noble Count, to request your patronage for this work. In addition to occupying the Presidency of the Royal Metallic College, you are deeply skilled in mathematics and physics; which you owe to a happy combination of great abilities with equal industry; whereby you doubly deserve the laurels which Sweden has bestowed upon you. If, then, these Miscellaneous Observations should gain your approval, it will be accepted as a sure sign that the same meed awaits them from the learned world, by,

Most noble Count,

Your most obedient and humble Servant,

EMANUEL SWEDENBORG.

MISCELLANEOUS OBSERVATIONS

CONNECTED WITH

THE PHYSICAL SCIENCES.

PART I.

MISCELLANEOUS OBSERVATIONS.

PART I.

On the different kinds of Mountains in Sweden, with a disquisition on their origin.

It is important to note the various positions, differences and characters of mountains, as clearly indicating the effects of the universal Deluge. In Sweden, there are mountains, 1. which lie in strata, consisting of white clays, sand, scissile, calcareous and many other kinds of rock, generally arranged in layers. Many mountains of this kind are seen in East Gothland, West Gothland, Gothland, and almost every other province of the kingdom; they are frequently from three to ten miles in length, and from a quarter to half a mile broad. 2. There are other mountains composed partly of strata, and partly of granite *(saxum griseum)*; in West Gothland we meet with examples in which the upper crust is formed of common hard granite, with strata of scissile and calcareous stone underneath it. 3. Some mountains, of considerable size and extent, consist of pure clay of different colours, and others of pure sand. 4. Some are formed of sand, intermixed with pebbles; the latter round and polished, as if turned in a lathe: immense mountains of this description, frequently a hundred and fifty ells* in height, are observed in Westmannland, Dalekarlia and Upland. 5. Others appear to consist of pebbles only, without any sand, all most curiously turned. Great chains of this kind exist in different parts. 6. There are many which seem to be formed of enormous stones, like fragments of mountains piled together: I have frequently perceived them at a distance of several miles, although their breadth seldom exceeds more than from thirty to fifty paces; their

* The Swedish ell is equal to 1 foot $11\frac{7}{10}$ inches English measure.

sides are generally very precipitous. The spectator may well be astonished on finding that these ridges, from the very bottom upwards, consist solely of the large fragments just mentioned, all mingled together, and each probably weighing from ten to forty Swedish naval pounds *(skeppund)*. Nor must we omit to notice, that the provinces are strewn with these vast boulders, like pieces of mountains, even where there is not a hill in the neighbourhood; notwithstanding which they are often found in the plains, at the bottom of lakes, even on the very summits of other mountains, which may appear paradoxical to those who have not had opportunities of observing the same in their own districts. The province of Helsingland and the district of Orebro are full of these remarkable specimens, spread like buildings over the level country. 7. Nor must we omit those mountains that consist of common hard granite; some of which are divided into strata, but comparatively large and unequal, whilst others again are not stratified; this kind of rock or mountain is seldom found elsewhere. 8. Adjoining the latter there are also calcareous and silicious mountains of different colours, and mountains of chalk and limestone. 9. Besides different kinds of minerals, impregnated with copper, iron and silver.

It may further be observed, that the ridges of most of these mountains, both of those which are stratified and of those which consist of accumulated heaps of sand, pebbles, stones, &c., run north and south. 2. Their sides are generally shelving, but the degree of the slope appears to be influenced by the substances of which they are formed; those consisting of sand are not so steep as those formed of large masses of stone, which may be accounted for by the slipping of the sand. 3. In West Gothland, there is a mountain called Kinnekulla, one of the loftiest in Sweden, of a pyramidal shape, rising at first in a gentle slope from a broad base, and gradually shelving until at last towards the summit its ascent becomes quite perpendicular. This mountain is situated between two others that run north and south, called Billingen and Hunneberg, which seem like ramparts to the Kinnekulla, the latter appearing to have been formed in their very gorge, within their projecting lips; as if the water had burst through the aperture, and at length standing between them, had deposited the argillaceous sediment or

matter that it brought with it; adding stratum after stratum with every fresh current, until the mountain reached the present altitude. On another side, the great lake Wenner lies at its base, and presents a hollow corresponding to the elevation of the mountain. We need hardly speak of the different substances of which the latter is formed, further than to remark, that the base itself consists of limestone strata of different kinds and colours, succeeded by scissile argillaceous, which in some places is as perpendicular as a wall; then we have the harder scissile and black calcareous rocks; some part also consists of the common granite. Pyrites and various other stones are also found there; the pyrites, in particular, is very rich, and deserves to be classed amongst the rarer ores of Europe.

From the above facts we may conclude that all these formations have been produced in some very deep or universal diluvian ocean, which is proved by the following considerations. 1. The mountains consist of substances of such different kinds, as sand, clays, smooth pebbles, large stones, and masses of rock. 2. Their slopes indicate that they were thrown up by the sea into great accumulations, and so formed into lengthened ridges, with shelving sides. 3. These ridges run north and south; which shews that the same winds prevailed in the diluvian as in the present ocean. The cause of the variation of the winds in the inland seas, (for example, in the North Sea, the German Ocean, the Baltic, the Mediterranean, &c.,) seems to be owing to the neighbouring shores and countries, by which the winds are turned, or compelled to alter their direction; this however is not the case in the Ocean, where the winds are known to blow nearly always from the same quarter, and indeed generally from the east or west. If, therefore, such large masses and accumulations of clay and sand could be moved by the power of the sea, this must necessarily have taken place under the influence of these easterly and westerly winds, which would determine the direction of the mountain chains: and this indicates that the ocean we are speaking of was universal, and stood at a great height above the land, and had no limits, shores, or straits to warp the winds, or cause them to blow to new and unusual quarters.

But should the reader ask how the ocean could carry away

stones of so vast a size, and pile them together, he will find his answer in the principles of hydraulics. It is well known, 1. That water presses according to its depth; so that its pressure on bodies or stones at the bottom is greater at a considerable than at a small depth; which indeed cannot be denied. 2. It is likewise known, that when the sea is in motion, not merely the water on the surface, but that at the bottom also, rolls and fluctuates; when therefore a tempest arises, the bottom is often thrown upwards, and the water rendered turbid; in the same way as in the atmosphere in which we live, we perceive that the air is in commotion, and driven into waves at the bottom, as well as at a greater height. 3. If therefore the waves give an impulse to the sea at the bottom, and water presses according to its depth, it follows that the water rolling at a great depth, is carried on with greater force and weight, in the same way as a large and heavy ship strikes against any obstacle with greater violence than a small or light vessel, though constructed of the same kind of timber. A wave at the bottom of the sea acts in a similar manner, and owing to the power derived from the weight of the superincumbent water, rushes with a greater impetus against any masses of stone, or other obstacles, and carries them away with facility. 4. Therefore, as the bottom of the sea was covered with different sorts of stones, sand and clay, it is by no means extraordinary that a wave of very deep water continued towards the bottom should have had sufficient power to bear away in its current stones of enormous bulk, and after having torn them away from their foundations, to strew them about in heaps, or pile them into mountains, and thus to form ridges, or cover whole provinces with them. 5. Hence we see that mountains of this description generally extend from north to south, that they contain stones that have been rubbed and polished, mixed with sand, and scattered about in various directions. 6. These stones also exist in the greatest quantity in those places which are now at the highest elevation above the sea, as in the province of Orebro, which is situated between two seas, at a great height above their present level; namely, from seventy to eighty Swedish ells, in which province they are indeed most abundant. The reason of this is, that as they could only be moved by the deeper waves, if the sea

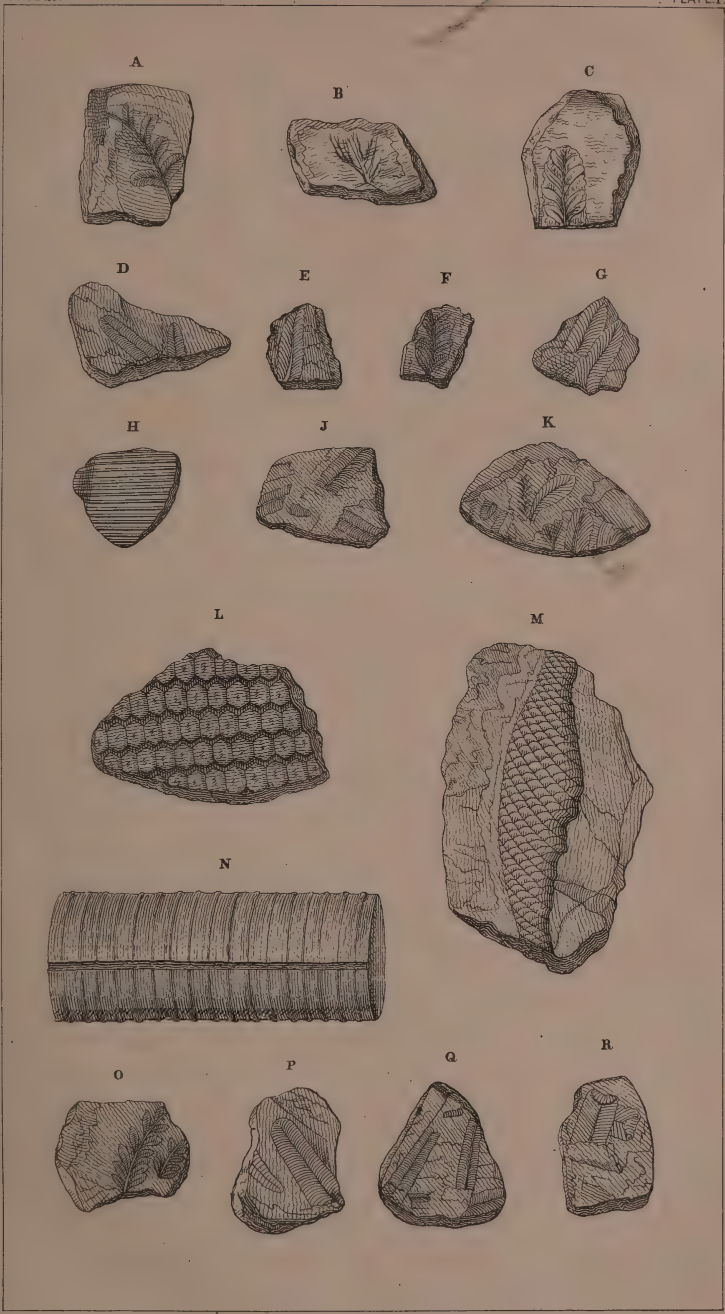
had sufficient power to carry them to the highest parts of this district, they would necessarily stop there, and travel no farther, since the force in the water diminishes with its depth. 7. This view appears to be confirmed by calculation; for stone is heavier than water in the proportion of about $2\frac{1}{2}$ to 1: but when placed in water, it loses a part of its weight equal to 1, so that in this case, it only weighs to that element as $1\frac{1}{2}$ to 1; and still less in salt water. When the bottom of the sea, therefore, is agitated, it follows that the deeper waters possess sufficient power to transport weights hither and thither, although heavier than water in the proportion of $1\frac{1}{2}$ to 1: as is indeed proved by torrents, which frequently tear away masses of stone, and overthrow walls of solid masonry. Dykes, though built of stone, are overthrown when the water rises three or four ells higher than usual, owing to the power which it immediately gains by the increase of depth, as I have myself known to occur in Sweden a hundred times. Another proof is afforded by the power of our atmosphere, which carries away bodies a thousand times heavier than itself, and conveys them to a great distance. Do we not often see heaps of sand whirled off in a storm for a thousand paces? Also dust, wood, bark, trees, and many other bodies a thousand times heavier than the atmosphere? This appears to be owing both to the increased area of small bodies, and to the weight of the atmosphere moving at the bottom, *i.e.* on the surface of the earth. In a similar manner the Ocean, in gales of wind, produces an irregularity, often extending for miles, in its shoals and sand-banks, and likewise at its own bottom. If then the atmosphere, though a thousand times lighter than water, can exert such a force on heavy bodies, as to transport them from place to place, what must have been the power of this mighty and ponderous ocean? This gives us some glimpse of the origin of mountains; provided the cause assigned is worthy to be accounted geometrical.

On the Petrified Plants found at Liège.

Although at the present day large collections have been made of different kinds of petrifactions, it may notwithstanding be desirable to notice certain plants found in vast quantities

at Liège, in one of the strata of a mountain situated near the monastery of the Chartreux. It is to be observed, 1. That the stone in which they were found is a soft scissile of a brownish grey colour. 2. This mountain rises about seventy ells above the city of Liège, or about eighty above the river which runs through the city, so that we may fairly calculate its height at about a hundred ells above the present level of the sea, if we take into consideration the descent of the river towards the sea. 3. The ridge or back of this mountain lies nearly north and south. 4. The stratum inclines from west to east at an angle of about sixty degrees, like the other strata. 5. The vegetable stratum is of considerable thickness; on one side of it there are layers of sandstone, and yellow clay; at another side there is the same argillaceous scissile as the stratum itself; on the third, we have fossil coal of the best quality; and on the fourth, the road. 6. On their upper surface, these sloping layers are covered horizontally with a black stratum which runs toward the fossil coal; above this, with a layer of white clay, next with yellow clay, and lastly with the soil. 7. And what is more remarkable, the whole of this stratum is filled with vegetable remains, and in every few pieces of the stone we can hardly fail to find petrified stalks and leaves; indeed, it might appear as if a number of haystacks or part of a wood had been rolled down hither by the sea. This furnishes an indubitable evidence that an ocean formerly stood at a height of at least a hundred ells above the level of the present sea; an ocean which uprooted the inhabited land with its fruits and herbs, and promiscuously mingled sand, clay, and rock in vast accumulations.

The vegetable specimens to which I have alluded, were collected by myself and my travelling companion, Doctor John Hessel, physician to the province of West Gothland, and well skilled in the botany and fossils of Sweden. They are as follows:—1. ACFO are all leaves of nearly the same species, except that some have the stripes running obliquely upwards, which in others are horizontal, or parallel. 2. DJPQR are, as I suppose, leaflets from these stalks, but of a larger size, particularly the specimen P; in the leaflet E the stripes are oblique. 3. B is a small branch. 4. G and K are leaflets. 5. Innumerable petrifactions of stalks and stems were observed. 6. H is



PETRIFIED PLANTS AT LIEGE

a piece rounded on two sides, with straight grooves proceeding from a certain small line. 7. L has the appearance of an ear of Indian corn, or maize, except that it is flat. 8. I am in doubt whether M be the scales of a fish, or the fruit of a tree. 9. N is a species of Belemnite. The same fossils are still found in this stratum, and whoever pleases may procure thousands of specimens.

On the Strata of Shells at Aix-la-Chapelle.

In further proving the existence of a diluvian ocean from mountains and mountain strata, we can have no clearer corroboration than is afforded in the high mountain of Lousberg, situated near Aix-la-Chapelle, on the north. 1. This mountain rises about eighty ells above the city, and about a hundred above the level of the sea. 2. It consists in a great measure of sand, which, on external examination, we should confidently assert was hard stone, as it has the colour and form of stone, and may be removed in square blocks. On examining it internally, we observe the same graining and arrangement of particles as in the stone, shewing, unless I am mistaken, that this mountain has been softened into sand. 3. The top of the mountain on one side consists of sand mixed with earth; under this we have a layer of pure calcareous pebbles, but very unequal in size; and next, a layer of perfectly white stone, divided into square masses, exactly like entire limestone. 4. Then comes another layer of very irregular stones, flints, &c. 5. On another side the mountain consists of sand, and shells of various descriptions. 6. A stratum of sand then follows, and next an intermediate layer of shells. 7. More than ten layers of the latter may be counted, some an ell in thickness, others a half, a third, or a quarter of an ell; the distance between them being from one to three ells, while the intervals are formed of pure sand. 8. I have figured these shells, of which we found more than thirty in one piece of the stratum; which piece indeed seemed like a conglomerate of them; but owing to the difficulty of separating them from the stone in a perfect condition, I have only shewn the principal ones.

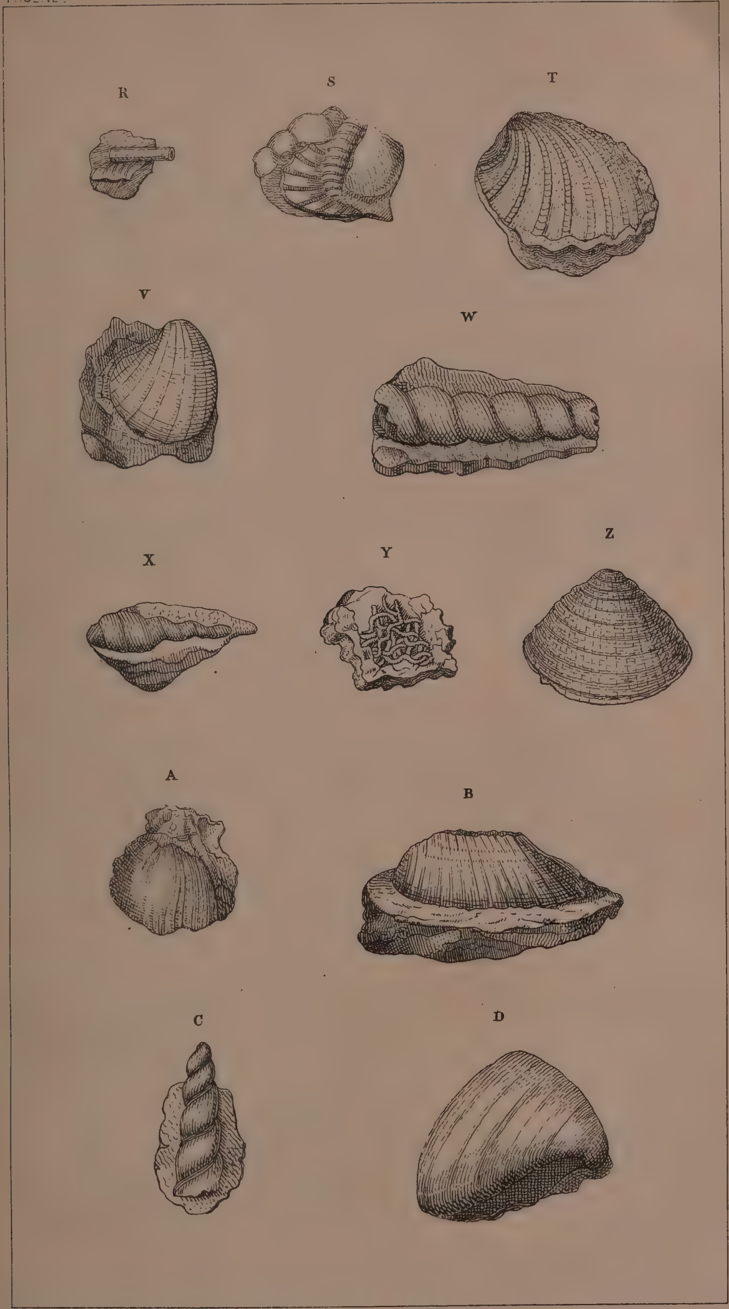
Amongst the whelks, oysters, and other bivalves, there are,

1, some, as Fig. T, with oblique lines or furrows, and granules distributed along them. 2. Some, as Fig. G, have the lines or stripes without the granules. 3. Others have fine lines of two kinds; as Figs. F, Z, M, H. 4. BD, &c., are univalves. 5. One shell filled with smaller ones, and containing a turbinite, is shewn in Fig. E. 6. Figs. S, X, C and W, are turbinites of various descriptions. 7. Y is a mass of little worms. 8. Fig. K is the shaft of a reed. 9. Fig. R, little shells.

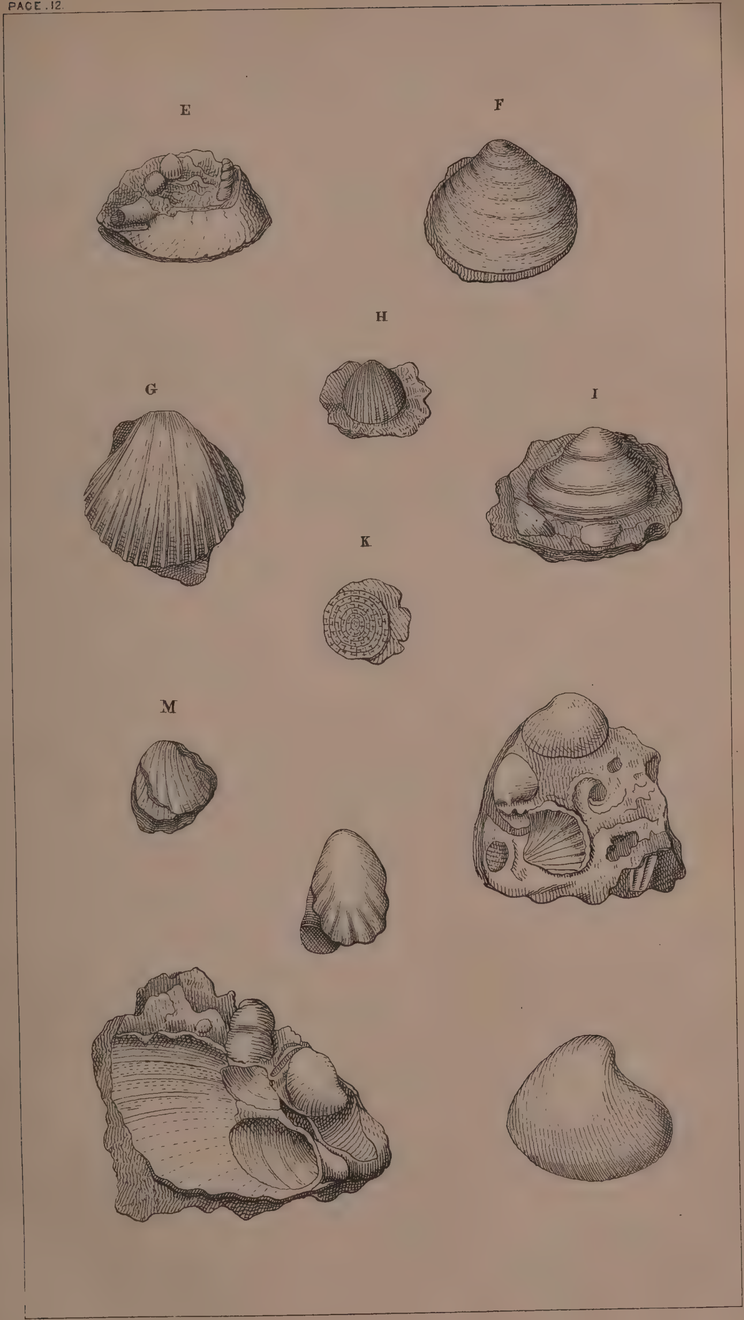
It is also observable that, 1. Some of the strata and shells are very soft, and whitish yellow; some are red, or brown: some crumble to pieces when touched; some are partly sandy, partly calcareous; and the soft substance effervesces with nitric and vitriolic acids. 2. Some shells are evidently crystalline; the valves consist of pure crystal; which in some specimens is like the clearest glass, whilst in others it resembles yellow, green, or smoked glass, &c. 3. The crystalline substance forming the valves is in some cases extremely brittle, but always cleaves in hexagonal cubes. 4. Some of the shells contain innumerable small crystals, besetting their internal surfaces. 5. Some of these strata and shells are exceedingly hard and quite petrified, and can scarcely be separated with a hammer. 6. Others are calcined and decayed, of a muddy, yellow, grey, brown, or red colour, and crumble into dust. 7. And I have observed that between the valves of one shell, a number of small ones were concealed, viz., little bivalves, turbinites, and pectinites, which seemed to have taken refuge in the cavity of the larger shell.

We may conclude from this variety of petrifactions, that a change of things has taken place in the bowels of the earth by the agency of fire and water; and also that the primeval ocean was a hundred ells or more above the present ocean, since we see that, at such an elevation, more than ten strata are formed of nothing but shells. If any one should wish for specimens in proof, he may procure heaps and waggon loads from these strata, and a single piece of stone will afford him nearly all the varieties he desires.

In like manner, there is a very thick stratum of shells at Bahus, near Norway, in a mountain ninety ells, at least, above the level of the sea. These shells are so plentiful, that



SHELLS AT AIX LA CHAPELLE


E
F
H
G
I
K
M

the inhabitants burn them as affording the best lime, which is sold throughout the whole district: not to mention innumerable other instances.

On the harder Strata, consisting of the common Granite; and their origin.

I was surprised at discovering amongst the strata in several localities, some consisting entirely of granite, of the same kind as that usually found in mountain-chains, such as the Alps and most of the northern mountains, which have been hitherto regarded as contemporaneous in their origin with the earth itself, and as having occupied their present position from the very beginning. Nevertheless, that they were once soft and argillaceous, is evident from strata of the same granite existing in several places. Thus:—1. In West Gothland, in the Billingen mountain, which is three or four miles in length, the upper stratum is pure granite. 2. Beneath this, there are calcareous, scissile, argillaceous and other strata, containing petrifactions of various kinds, as shells, insects, especially marine animalcules. 3. The above stratum of granite is seven or eight ells thick, and divided in two places. 4. There is a horizontal division on the under side, viz., between the granite and the calcareous and scissile stones below, which division appears to have been produced by the action of a watery surface. 5. These stones are as hard as the granite, and will take a polish; they are also of the same colour, and cannot be converted into lime; so that they do not seem to differ in any respect from the common granite of which mountain-chains are composed. 6. The same observation may be repeated in many other mountains in the above province, as in Mösseberg, Hunneberg, and on one side of Kinnekulla, whose summit consists of a very thick crust of granite, with layers of calcareous, scissile, and other kinds of stone beneath it. 7. This granite generally breaks in cubical masses; hence the stratum stands out perpendicularly, and fallen fragments lie scattered at the foot of the mountain. 8. In the province of Bahus, there are mountains of this granite, divided into very thick layers or strata, which, however, lie in an oblique position. 9. Near

Liège, and in other places, I saw a layer of this same hard granitic rock between the argillaceous and scissile strata.

From these observations we may conclude, 1. That the matter of the common granite was once argillaceous, though of a very fine description. 2. That, together with the other strata, it originated at the bottom of the diluvian ocean, as is proved by its also lying in strata, and having calcareous, scissile, and other rocks beneath it, which are occasionally full of marine remains.

But that this primeval or argillaceous matter was finer or more subtle than the other substances, is clearly shewn by the circumstance, that no insects, marine animalcules, or plants are found in it. This view of ours may be elucidated by experience, and is supported by the following experiment. I took some very fine powder, which I had scraped with great care from the hard rock, and mixed it with water in a capacious glass vessel; when I had shaken it up for a long time, I set the vessel aside, to allow the powder to settle gradually. As it was so fine, 1. It subsided very slowly in the water, the process occupying many hours; nevertheless, a sediment was always formed. 2. When the fluid had rested for six hours, and I had reason to think that the powder had subsided into a compact mass, still I found that on slanting the glass, the whole of the thick sediment or mixture obeyed the same direction. 3. I then dropped in a little sand, which passed through the matter to the bottom. 4. When I placed a shaving of wood with great caution at the bottom, it quickly rose to the surface, through the thick matter. 5. In the same way, small fish were able to rise from the bottom to the surface, and could swim as well in the denser as in the thinner substance. 6. So that for many hours the sediment retained a fluid character, although dense and thick. From this experiment, I think we may conclude that the powder from which the granite mountains originated was extremely fine, that it subsided very slowly, and retained its fluidity for a long time; and that consequently hard substances would sink through it, those of a softer and lighter nature, such as wood and plants, would rise to the surface, while marine animalcules and other living creatures would escape out of it, before the stony or argillaceous matter had time to assume too great a consistence.

Afterwards, however, when the powder had rested for two days, it became somewhat more fixed; yet it parted with its fluidity by very slow degrees; for on disturbing the surface of the water, the surface of the powder likewise was set in motion and rendered uneven. Hence again we may conclude, that the inequality of granite mountains is partly owing to the water on their surface fluctuating, or being otherwise agitated and disturbed. To recapitulate; as the surface of this comparatively soft matter would be influenced by the motion of the water, the inequalities on that surface may have been occasioned in the above manner; and it appears therefore that the powder of which granite consisted must have been far more subtle than that of other hard substances.

On inclined Strata, and the causes of their inclination.

On observing the strata in different localities, we perceive, 1. That many of them lie in a horizontal position. 2. Some are inclined at a small angle, others are more oblique, being 10°, 20°, 40°, or even 90° from the horizon, and this obliquity takes place towards the right, as well as towards the left. 3. Some strata run in a circular curve, of which two examples occur near Aix-la-Chapelle; one of them following a convex circular direction, whilst the other assumes the opposite, or concave circular form. 4. Others are in curves of a different kind, as the elliptic, parabolic, &c. 5. And frequently one part of the same layer is less oblique than another; the upper part more inclined than the lower, and *vice versâ.* 6. These oblique inclinations are not directed towards any particular quarter; but sometimes are towards the south, sometimes towards the north, east, &c. 7. The upper strata frequently lie in a horizontal position, whilst the lower are more or less oblique, as I have remarked at Marburg and in other places. 8. Sometimes the strata in the same mountain assume a serpentine direction, that is, in one place they incline towards the east, and in another towards the west; sometimes they rise up and down four or five times in one hill, as is the case under

the Castle of Blanckstein, between Dillenburg and Marburg; also near the city of Cassel, there is a circular incurvation in the part where the strata mutually recede from each other, but elsewhere it is not so, &c., &c. In the hope of ascertaining the causes of this arrangement, I performed the following experiment. 1. I shook pulverized clay and water together, and allowed the mixture to repose; whereupon a horizontal stratum was formed at the bottom of the vessel. 2. On pouring in an additional quantity of muddy water, another stratum was formed upon the lower one, and so on, three or four times in succession; as will be mentioned again hereafter. 3. But these strata combined, and gradually settled into a close mass, within a period varying from twenty-four to forty hours. 4. When I placed a stone which sloped on every side at the bottom of the vessel, as at G, Fig. 41, a stratum was formed upon it, which assumed a horizontal direction; the clay, being deposited horizontally at the sides of the stone, did not seem at all influenced by their obliquity. 5. The same result took place on forming additional layers above this stratum. 6. But on leaving them in a state of repose for a whole day, they subsided more and more; the stratum *a* sinking down towards *c*, the latter towards *e*, and so on. 7. When these strata had gradually subsided, and became more closely united, a greater sinking had taken place where there was a greater depth of the soft substance, as on the side *ah*; but above the stone at *mn*, where there was but little matter which could subside, it had not, of course, sunk so much. 8. The wider intervals between the strata may have been produced in this manner. If therefore the mountain ridges, sands and other substances at the bottom were thrown into heaps by the ocean, they would form an uneven surface, and when the strata were deposited upon this foundation, they would be bent into circles, curves and angles more or less acute, according to the inequalities at their base. At least, some kind of subsidence appears very certainly to have taken place, which I am inclined to attribute to the means stated above; but in matters of such antiquity, it is only by conjectures and experiments that we can obtain any insight into their causes.

On the causes of the varieties in Strata.

Great diversity exists in strata composed of the same material. 1. There is a considerable difference in their hardness; thus scissile, resembling clay of the same kind, is sometimes intermediate in hardness between clay and stone, and sometimes it is very hard indeed. 2. They differ greatly in colour also, for we find that strata of the same kind are either grey, brown, yellow, red, blue, green, or black. 3. Strata are sometimes softened into clay, bole, sand, and ochre. 4. Some strata are impregnated with vitriol, alum, nitre, or other salts or minerals. 5. Others are converted into lime, chalk, fossil coal and other substances, which owe their origin entirely to changes that have taken place at periods subsequent to the Deluge; we are confirmed in this view by finding that one stratum differs greatly from another lying close beside it; as a stratum of fossil coal from a neighbouring scissile stratum, &c. The causes of this appear to be as follows: 1. Fluids, as fire, oil, water, &c., will permeate the strata obliquely upwards, and arrive at the surface between their planes of contact. 2. If water, tinged and impregnated with the salt, sulphur, &c., of other strata, filter upwards, the substances through which it passes will be tinged in layers thereby. 3. If a stratum be in an oblique or horizontal position, the fluid penetrates in the direction of its layers: heat also follows the same course, but only upwards; oil or asphaltic matter likewise; water tinged with salt, alum, nitre, vitriol, or other bodies, creeps also along the strata; and any sulphureous or mineral exhalations accompanying the hêat or water follow the same course. 4. And wherever the fluid penetrates, it impregnates both the surfaces and the substance of the strata, and consequently occasions changes in their matter, salts, sulphur, hardness, colour, &c. 5. Hence we find that whole strata have undergone a change, whilst others in their immediate vicinity have remained untouched; because the fluid had forced a passage between the planes of contact of its own stratum, and had impregnated the surfaces by infiltration. Thus a vein of fossil coal frequently has a scissile stratum near it, varying in hardness and shade of colour; and a stratum of limestone may lie next to one of clay, sand, &c. 6. This result may be shewn expe-

rimentally by dipping the bottom of a scissile stone in oil, and the other part in water; when the oil will be seen penetrating between the layers of the stone, from the bottom upwards; the water also will do the same; as will be clearly shewn in the following pages in our experiments with sponges and spongy substances.

Observations, and points to be observed, concerning Strata, their separation, arrangement, and differences.

That strata of such different kinds originated in a universal diluvian ocean, will not, I apprehend, appear at all doubtful; the following experiment may throw some light on the manner in which the layers were formed in it. 1. I took a sort of pulverized clay, and mixed it with water in a glass vessel, which I afterwards shook repeatedly, so as to mingle the contents thoroughly together, and render the fluid equally turbid throughout. 2. I poured a part of this muddy water into another glass, which I placed aside for several hours, until the clay had subsided to the bottom. 3. I then added another portion of the muddy water, and left it also until its clay was deposited. 4. I then added a third and a fourth portion. 5. And I remarked that the clay had settled down in layers, one stratum above another; and that they appeared distinctly separated from each other, because the subsidence had taken place at different times. 6. On leaving it at rest for a still longer period, the clay became more and more compact, and hardened spontaneously, although the water remained above it. 7. The water being then drained off, and the sediment allowed to dry, (which required the utmost care,) the layers separated from each other spontaneously. Now the same might have taken place at the bottom of the ocean, for as its waters were rendered turbid by the clay, they might, whilst tranquil, have deposited it in a pulverized state at the bottom; other layers might afterwards have been added, which could be distinctly separated, as was the case in the glass vessel. This separation would be promoted by the waters flowing off, for in this case the process of drying would naturally cause the strata to shrink and contract above and below, as far as the central line; thus producing a division

into layers, with intermediate spaces, wide in proportion to the thickness of the strata; these intervals were afterwards filled with some other fluid or substance.

Secondly : We have to observe, that no regular order is kept in the strata; that the light substances do not always lie above, nor the heavy below, unless they were deposited at the same period; that is to say, unless the heavier and lighter matters have been mixed together and subsided at the same time. For, 1. On throwing a little sand into the layers of pulverized clay mentioned above, it sank through them to the bottom. 2. But when the clay had acquired a somewhat firmer consistence, and had formed a stratum, the sand no longer passed through, but settled in a layer above it. 3. When clay, fine sand in powder, coarse sand, and iron filings were mixed together and well shaken, the metallic particles first sank to the bottom, then the coarse sand, and afterwards the fine sand mixed with the clay. 4. The same effect was produced by using one sort of matter, but decreasing in bulk, such as coarsely and finely pulverized clay; the larger pieces subsided first, and were followed by the lighter or smaller parts. These experiments lead us to the conclusion, *firstly*, that in those deposits which were formed at the same period, the heavier substances were the first to subside, and afterwards the lighter; or that the larger pieces were the first, and afterwards the smaller. *Secondly*. That if these deposits were formed during a long period, or successively, the lighter matters might occupy the lowest place, and the heavier lie at the top. *Thirdly*. That owing to these causes, there cannot be any certain arrangement of the strata or their particles. I have sometimes observed the scissile above, with sandstone beneath it, and limestone lower still; sometimes the limestone has been uppermost, then came the sandstone, and then the scissile; occasionally the grey or common rock has been placed above the limestone, of which many examples may be seen in Sweden.

For instance, I will mention a few near Helsingborg, in Schonen. There is, 1. An upper stratum of soil or earth. 2. The next is clay. 3. The third is sand. 4. The fourth is a soft scissile of a blue colour, which deliquesces on exposure to the air. 5. The fifth is likewise scissile, but harder and darker

coloured. 6. Then comes a vein of fossil coal, one foot thick. 7. The seventh is clay of different sorts and colours, four ells deep. 8. The eighth is soft sandstone. 9. The ninth is a harder kind of sandstone, fit for grindstones; for which purpose it is quarried. 10. The tenth is a grey sandstone, and then a red variety. In other places the arrangement is different, as in Mount Bellingen; where, 1. The surface is covered with a very thick stratum of common grey rock. 2. Then comes a stratum of very hard black limestone, divided into thick layers. 3. Next, argillaceous scissile of various kinds. 4. Then there are different kinds of calcareous stone, red, yellow, and ash coloured. 5. The fifth appears to be formed of a softer description of scissile, which is succeeded by limestone, &c. The arrangement differs again in Kinnekulla and other mountains; so that we may lay down the rule, that where the bottom of the ocean has been stratified at different periods, the strata do not occur in any certain order as determined by their weight. This remark, however, is only applicable to those strata which appear on the crust of the earth.

Thirdly: It is to be observed that all hard stony bodies are formed in strata, excepting those substances which have been produced in stones during long periods. Thus we find, 1. That earths and boles of various sorts and colours, are deposited in layers. 2. Also clays of different kinds and colours. 3. Likewise different sorts of sand, varying in colour and fineness. 4. Sandstones again, varying in kind, colour, and hardness. 5. Scissiles, presenting the same variety. 6. Limestones, the same. 7. Gypsums. 8. Marbles. 9. Silicious and saline bodies. 10. The hardest stones of the common grey kind. 11. Talc stones of different sorts. 12. Stones already calcined, stony marl, chalk, and even strata of true lime. 13. Fossil coal.

As metallic ores are to be classed among vegetable growths, and as they insinuate themselves into the above-mentioned stones during long periods, so they are not found in strata like other hard stony bodies. Nevertheless, we meet with strata containing ores, as of iron, copper, &c.; also boles, clays and sands, rich in metals; there are likewise marcasites, sulphureous stones, aluminous and vitriolic scissiles, and layers of ochre; to say nothing of strata of shells and other marine remains, and of

pebbles and mixtures of various materials. We thus have some grounds for concluding that there is no kind of stone, unless its origin be extended over considerable periods of time, but may exist in strata; notwithstanding that the same kind may be found in the mountain-chains, as granite, limestone, sandstone, clay, &c.; which indicates, that primitively all hard bodies originated from clays, salts, and their combinations, and were formed at the bottom of the ocean.

Fourthly: The inter-strata should also be carefully examined; for, 1. They differ greatly from the strata. 2. Sometimes they consist of the substance which lies above the strata, and is carried down with the water. 3. Occasionally they are formed of the matter lying beneath, which is brought up by the water. 4. Hence the inter-strata are found to consist of various substances, boles, red ochres, clays, lime, pebbles, and sands, but not of the same substances as the strata. 5. Sometimes they contain a sulphureous and bituminous substance, or asphaltum. 6. They are likewise impregnated with metallic ores, as iron, copper, and silver; or with vitriolic and aluminous minerals. 7. They occasionally contain the nobler substances, crystals, &c. 8. Also waters of various kinds, which have been impregnated by the surfaces of the layers through which they have passed, and impart their qualities to the surfaces of fresh strata. Almost every change observed in the strata, is produced by the penetration and infiltration of exhalations, spirits, and waters through the interstices; consequently they will well repay our attention, and will help us to very many conclusions respecting the changes that have taken place in both hard and soft bodies since the diluvian period.

Nor are the substances imbedded in the strata less worthy of observation. Thus we have, 1. Plants, shells, animals, &c. 2. It frequently happens, that some of these remains are found entire, some are indurated, whilst others are softened into lime, and others into clay, sand, or bole; others again are converted into flint, stones, crystals, and many other substances. 3. Various hardenings sometimes occur, and different stones result; in one case siliceous material, in another calcareous, at one time bacon stone, at another crystals. 4. Or into still nobler substances, as diamonds, &c. 5. Sometimes the matters

contained are fluid, as asphaltum, bitumen, or water. 6. Hence also we have the various kinds of marcasites, minerals, metallic bodies, and some in a native state. 7. To say nothing of artificial and figured stones, which exist in a great variety, as belemnites, ætites, entrochi, as well as grained stones, crystals, &c., &c.

On Stony Marl or Margenstein.

Stony marl is a kind of stone which has been calcined, perhaps by subterranean heat; it is divided into cubical pieces of a soft consistence; it is soluble, and yellow or ashy grey in colour. 1. This stone, whilst entire, and before it is dissolved, effervesces briskly with oil of vitriol and other acids. 2. When pulverized and mixed with diluted oil of vitriol, it effervesces for a long time, and emits a little vapour of an aromatic odour; the glass vessel becomes warm, and the solution afterwards grows clear, almost like water, except that it is pale green; a white feathery sediment is deposited at the bottom, and I remarked that whilst the effervescence lasted, a thin fume passed over the glass. 3. Spirit of nitre causes it to effervesce differently. 4. If the solution in oil of vitriol be diluted with water containing a little syrup of violets, it assumes a beautiful opalescent red tint. 5. The powder is not altered by the spirit of sal ammoniac, but the spirit itself is very speedily absorbed by the stone: nor is it changed by a solution of alum, vitriol, or nitre. 6. It is not soluble in water, although it becomes heavier and somewhat harder. 7. When exposed to the action of heat, it becomes more soluble, spontaneously crumbles to powder, and is calcined: hence it is that houses built of this stone decay the most on the south side.

Fossil coal contains this kind of lime between its layers, as is evident from the following circumstances. 1. A sort of lime is found between the strata of coal, in small bluish-white layers; which, like marl, effervesces powerfully with oil of vitriol and spirit of nitre, and affords nearly the same results as marl in other experiments. 2. If pulverised fossil coal be digested in water for three or four days, the water is very limpid, like this solution of lime. 3. The water in which the coal is digested

FIG.1.

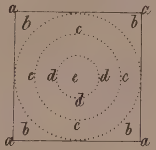


FIG.2.

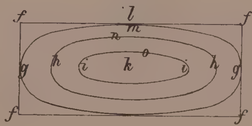


FIG.3.

FIG.4.

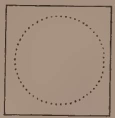


FIG.5.

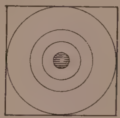


FIG.6.

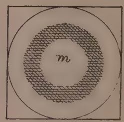


FIG.7.

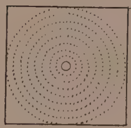


FIG.8.

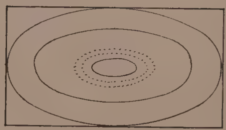


FIG.9.

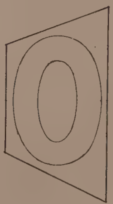
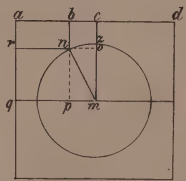


FIG.10.



effervesces a little with oil of vitriol; it grows warm, fumes, and the coal rises to the surface, whilst the lime is precipitated to the bottom. 4. Coal is sometimes found near this lime, as experience testifies, in several places.

On the Circular Crusts found in certain Stones, and on Mountain Nuclei.

In a mountain consisting of different kinds of strata, in the neighbourhood of Liège, near the monastery of the Chartreux, I remarked that, 1. a stratum nearly an ell thick was divided into several lesser strata; it consisted of a hard sandstone, like that used for sharpening scythes and similar instruments, and was everywhere divided into cubic blocks, square and oblong. 2. Each block, when broken, contained circles distinguished by a certain colour, from the surface to the centre. 3. The external surface was brown, the circle next to it was a lighter brown, then came rings of green, and lastly of yellow. 4. These coloured circles were but of little thickness, and the stone between them was almost colourless; but when the material was coarse and soft, the circles were somewhat larger. 5. In the softer stones, these circles were two or three inches apart; but in the hard, they were nearer to each other. 6. In large cubical blocks of the stone, the distance between the circles was nearly in proportion to the size of the stone, so that they were not more numerous in a large than in a small cube. 7. In the hard stones I noticed that the circles were not so far apart, and much more numerous, there being more than ten to be counted in a hard specimen, whilst in a soft piece there were but two or three, and those at a considerable distance from each other. 8. The colour also varied. 9. When the piece was exactly cubical, and every side was a square, as in Fig. 1, the first circle *bbbb* was not exactly round, the next *cccc* was rounder, and the third, *ddd* was exactly spherical. 10. In the oblong pieces shewn in Fig. 2, the first coloured ring *gg* was not exactly elliptical, the next was more so, and the third and fourth *ii* were true ellipses, or ovals. 11. When the blocks of the stratum were of a different shape, the curve also was of a different kind, but always approaching the circular. 12. The cubical blocks I observed in

this stratum, were of considerable size, measuring from one-third of an ell to a whole ell on each side. There were other harder strata: one of which was but two inches thick, and had near it many other strata of the same substance; it was divided in the same way into cubical portions, of a square, oblong, or other form; each of these portions could be removed separately; they were of small size, measuring two or three inches across.

In examining this stratum, I observed that, 1. Every piece or block had a nucleus, with circular layers from the circumference to the centre: and as there were myriads of the blocks at hand, I broke a great number to make this observation. 2. The external square crusts or surfaces were hard, and of a ferruginous colour, like well-burnt brick. 3. Within this square or otherwise cubical crust, there was frequently one nucleus of a soft yellow substance like clay or yellow ochre, which crumbled to powder between the fingers. 4. Other pieces contained the same matter, equally soft, but in two nuclei, as in Fig. 3, where the external part is a reddish, but the internal a paler, yellow. 5. In some, the whole cavity contained nothing but a dark bole, which was smooth to the tongue, and seemed to be a species of armenian bole, (see Fig. 4:) but this substance was in small quantity, and only filled a third or a half of the cavity, leaving the rest empty. 6. In others, the outside of the nucleus consisted of a yellow argillaceous material, as in Fig 5, whilst the inside contained this darkish bole, in small quantity. 7. In several, the central part was empty, presenting a mere cavity; round which, however, there was a nucleus of the usual yellow argillaceous matter. 8. In some, the centre contained a harder and almost stony portion, as in Fig. 6, where *m* is nearly of the consistence of stone, with a very small quantity of bole lying around it. In others there was a cavity round this stony part, the outer surface consisting of the yellow substance already mentioned. 9. In all in which there was a cavity, there was a partial roof or arch of yellow substance around the hard portion, as in Fig. 8; where the cavity was in the centre, the soft yellow part extended from the centre or cavity to the inner dotted line: the portion inclosed within the dotted lines was about as hard as a nutshell; the substance beyond this again was soft; hence in some pieces, the outward part was decayed, as in

Fig. 6, and the harder part inside it was larger, and contained a cavity, which sometimes was empty, sometimes full of bole. 10. Thus there were a kind of rudimental ætites, capable of being converted into true and hard ætites by the influence of the sun or the agency of fire. 11. In one specimen, Fig. 7, I counted eight soft layers, of a tawny, brown, and yellow colour; which could be loosened and peeled off by a slight force, but inside them, there was a circular stone of a harder kind. 12. When the pieces were exactly cubical, these nuclei or cavities were exactly round, as in Figs. 3, 4, 5, 6, 7. 13. But when the pieces were oblong, as in Fig. 8, the nuclei were oval, as well as the internal cavity. When the piece was of some other form, as in Fig. 9, the nucleus was neither circular nor elliptical, but exhibited a different curve, although the enclosed matters were circumstanced as in the others.

I also noticed another stratum of the same material, which was divided into pieces, each containing circles as in Figs. 1 and 2, but of a browner and more ferruginous colour; the number of these circles was however the same, but they were hard throughout.

At a little distance, there was a larger stratum, an ell in thickness, composed of the same substance as the nuclei; *i.e.*, of yellow clay or ochre, and equally soft. 1. Above this stratum there was a soft argillaceous scissile stone, spontaneously divided into blocks; and beneath it, an equally thick stratum of hard sandstone, next to which, was a layer of fossil coal. 2. The yellow stony marl or argillaceous ochre of the stratum, although of the same substance as the nuclei, only a little denser, yet presented no cavities or circles, but was homogeneous throughout. 3. I remarked other smaller strata, consisting entirely of this yellow marl. 4. The same kind of material was found in this as in the sand-stone, the same glistening particles of mica, the same coarse pulverization, as though they were of the same stuff, and only differed in hardness and colour. 5. These small strata of yellow marl had a layer of soft argillaceous scissile on each side of them.

I likewise saw, embedded in the same scissile, masses, which when removed were of a most irregular shape, exactly like large stones, and each of which, as far as I could judge from

its size, might weigh thirty Swedish naval pounds, or eleven thousand Dutch pounds. 1. Some five of these masses may be seen in this scissile, near the monastery. 2. They consist of the same yellow substance as the strata, or nuclei. 3. They are surrounded on all sides by the soft argillaceous scissile, and are embedded just like stones, without crusts or layers. 4. The same yellow material is observed surrounding belemnites, next to which comes a hard ferruginous matter, which encloses them like a crust, and which is especially seen in those specimens that are procured from the limestone of West Gothland. 5. It also surrounds certain petrifactions. 6. I was informed by my friend, Doctor John Hessel, that this limestone contains pyrites or marcasites, half of which consist of fine bole.

From all these facts, some conclusions may be drawn. Conclusions however cannot be positively true, unless innumerable data have cleared the path and illustrated the traveller, and therefore I only propose the following, in part as subjects for further scrutinizing inquiry; in part as materials for comparison with more numerous data. We conclude then that,

1. Some kind of fluid surrounded the surface of the stone, and penetrated into it, forming the circles described above; but whether this fluid was pure water, or whether it contained alum, vitriol, or lime, or some other substance, there is nothing at present to shew, but the subject must be left for farther enquiry.

2. When water filters in through the sides of a cube, it at last advances with a circular margin.

3. When water passes in through oblong surfaces, it advances with an elliptical border, which becomes more exactly elliptic as it nears the centre; the geometry of which will be spoken of hereafter.

4. Whilst the fluid is penetrating the stone, it stops at a certain distance before passing further, and staining the part where it is, in this way forms the circular divisions.

5. The fluid stops in the centre, and hollows out a cavity by eating away the stone. Hard bodies may be converted into

bole, particularly in the centre, as well as into a kind of yellow ochrey clay or marl.

6. Entire stones, embedded in the argillaceous scissile, seem to be converted into the same substance; and hard bodies may be softened by the reverse process of that by which soft bodies are petrified and hardened.

7. Ætites may be formed in the same way by the corrosion of the hard substances surrounding the stone; and belemnites by the previous corrosion of limestone.

But I was anxious to investigate this substance more fully; and, in the course of experiment, I found that this yellow marl, or argillaceous ochre, was of two kinds, similar, however, in colour and appearance. The first kind, 1. crepitated to a considerable degree in the fire, and split into a thousand pieces with a report like that of a pistol, and therefore did not admit of calcination. 2. I reduced this first kind into fine powder, and poured some acid spirit of nitre upon it; which occasioned a violent ebullition; and a similar result was produced by aqua fortis. 3. It gave out an odour, like that occasioned by dissolving iron in aqua fortis. 4. When the powder was digested for a long time in water, the water separated from it, and remained uncoloured. 5. When the powder was mixed with water, and oil of turpentine added, the oil would not mix with the powder which floated in the water, but was still colourless; nor was the effect different even when the oil was placed first in the glass, and the water poured on afterwards, in which case the latter, together with the powder, passed through the oil, and fell to the bottom; nor would they mingle when the oil of tartar *per deliquium* was added: but when mixed with oil of vitriol, the powder in the water became somewhat milky. 6. The cold infusion of the powder was changed from blue to brownish red by gall-nuts. 7. When the powder was triturated with linseed oil, it became a deep brown; with distilled vinegar, a whitish yellow; with water, the colour of the powder continued unchanged. 8. In other respects, this first kind of marl was comparatively hard, and pale yellow, but when pulverized, it was of an intense reddish yellow.

With respect to the second kind, 1. It was a coarser material and an argillaceous marl, and of a dirty yellow colour. 2. In powder it turned brown with linseed oil; dirty yellow with distilled vinegar; but with water it retained its own colour. It is used as a colouring matter at Liège. 3. It did not crepitate in the fire, but became hard, and preserved its colour, becoming however a little redder. 4. It did not effervesce with nitric acid or aqua fortis, but mixed with them without any manifest action. A third kind, of a dirty colour, and contained in the centre of the stones, was a very fine bole.

From these experiments we may further infer, that the first kind contained a ferruginous element, like the ochre found near acid springs; and that the second kind contained an argillaceous matter.

On the Primeval Matter of the Earth, with reasons for conjecturing that it was water.

Many hypotheses may be stated respecting the primeval matter of the earth and planets; but though nothing but conjecture can be claimed in treating of the remote antiquity of the creation, yet we shall here give reasons which seem to shew that the original matter of the earth may have been water. 1. It does not appear probable that fire was at that period encrusted, since the fire oceans, such as the sun and stars, keep in one place, and cannot be carried with a rapid motion (like that of the earth) in the sphere of their vortex. Then it may be doubted, whether experience can shew a single instance where any pure fire is encrusted, especially with hard* and liquid matter like that of this vast ocean; and whether, in the vortex of a planet formed of encrusted fire, centripetal gravitation would have place. 2. It seems more probable that a primeval, hard chaos, was divided into planets or earths; especially as the Sacred Writings appear to assert the fact. And it seems to be equally and as clearly deducible from them, that the original matter was water. Thus in the first words of the Book of Creation, it is declared that the Spirit moved upon the face of the waters, and

* Water, in the author's theory, consists of *hard* particles: see his chemical *Specimens*, and also his *Principia.—(Tr.)*

separated the waters above the firmament from the waters beneath. Let us suppose then, by way of conjecture, that water was the original matter; and we have the following arguments in confirmation. 1. The rotundity of the earth. For if this universal water first of all formed the earth, rotundity would be produced by the horizontal pressure on the fluid ocean. 2. Had the earth been hard, either in its own nature, or as a fragment of the chaos, it would have been more irregular and angular in its figure than it is. 3. All mountains, and all earthy substances that have been discovered, appear to have been soft originally; which is in some degree rendered clear by the preceding Observations. 4. This is especially the case with the crustal matter, as it seems scarcely possible to deny that the strata therein have had their origin beneath the ocean; also with the harder substances in the bowels of the earth, which are frequently identical with the crustal matter. 5. We are led to the same conjecture by the vast size of the ocean, which still occupies the greater part of the earth's surface. 6. And also, in some measure, by the universal Deluge; for the possibility of water being encrusted with hard matter is more evident than that the same could be the case with fire. And I think it may be shewn theoretically, that after the water was once encrusted, the ocean might again burst forth by the disruption of the crust; especially as the incrustation only takes place on the surface, and by the action of this incrustation, or change of liquids into solids, or of light bodies into heavy, the ocean necessarily subsides. 7. And principally, by the circumstance, that the primeval matter appears to have been elementary and fluid, and to have occupied a position beneath the lighter elements, and glomerated the earth into a sphere; and that in process of time the particles in the very deepest place and under the most enormous pressure appear to have been converted, either by disintegration or combination, into salt, and afterwards into all those bodies which take their origin and constitution from salt; that is to say, into saline mountains, argillaceous, oily, and stony substances of various kinds, &c. But these views are only put forth in the way of conjecture.

On the Subsidence of the Seas towards the North.

Experience proves that the seas are subsiding towards the north, and so perceptibly, indeed, that in less than a century, shores which were formerly immersed for a considerable distance are now left bare and dry. For example, 1, there are many towns in Lapland which once possessed convenient harbours, but at present are at a distance of three or four thousand yards from the sea. 2. Some cities in Sweden itself, as Upsal and others, have been separated from the sea coast by an intervening space of several miles, more or less, according to the slope of the surrounding country. 3. I have seen some places in Helsingland, which seventy or eighty years ago were covered by the sea, but now they are dry, and covered with large stones; so that at present the wheel rolls and the hammer resounds where a century ago the waves were heard; and fire and flame are smelting iron where formerly the waters flowed. 4. In various places amongst the mountains, especially in Upland, hooks and fastenings for ships still remain; anchors and timbers of vessels are also found on the hill tops, and in places forty ells above the level of the sea; not to mention the remains of whales and other marine animals. These facts clearly prove that the seas towards the north were formerly very high, but that in process of time they have sunk to their present level.

This subsidence has been placed beyond all doubt, and we may draw the following conclusions from it. 1. All the changes which have occurred in the crust of the earth were not caused by the universal Deluge, but some were occasioned by the sea formerly existing at a height of many furlongs above the present level, whereby certain strata were produced with the petrifactions contained in them; while others however are owing to the great diluvian ocean. 2. The northern countries in particular may have been covered by a deep ocean, whilst those situated more towards the south were left dry. 3. As this ocean appears to have subsided gradually, we shall not be surprised on finding that part of the land which at present is continental may formerly have been insular; for in this subsiding of the sea, the higher parts, as the hills and hill tops, would be the first to emerge, and the rest would be uncovered afterwards. 4. Hence

that celebrated writer, the late Olaf Rudbeck, was very probably correct in asserting in his *Atlantis*, that Sweden was by different authors formerly called an island, under the names of Atlantis, Thule, Scania, Mænheim, &c. 5. If it be true, as some maintain, that the seas towards the equator are but little elevated, or retain their horizontal altitude, we might conclude that the pressure of our vortex is unequal, and greater towards the poles than towards the equator; and that the shape of our globe is more circular and round at present than it was formerly. 6. This change must necessarily have occasioned a difference in the dimensions of the degrees of latitude, &c. 7. That the Baltic sea however is above the level of the Northern or German Ocean, is evident from the beds and the descent of those rivers, which almost cut through Sweden from Stockholm to Gottenburg; the highest district is Orebro, whence the rivers run down on each side towards the sea; and on calculating their course and altitude, we find that they have a fall of nearly seventy ells towards the German Ocean, but a much smaller fall towards the Baltic. Hence the subsidence of the latter sea towards the north may have been caused by its flowing into the German Ocean. But this is a subject which I leave to be discussed by others.

Observations and Experiments on the origin, temperature, and saline components of Hot Springs.

I am aware that many scientific enquirers have investigated the nature of thermal or hot springs with the utmost care and attention; nevertheless, without contradicting any of them, I wish to state my own opinion, in doing which I shall only describe such results as have been obtained by observation, without venturing farther than experience will lead me. In order however to understand what follows, we must take notice, that,

I. *Water cannot be in more favourable circumstances for rising above its level, as it were spontaneously, than when it is between thin strata or layers of stones.* To prove this fact by experiment, I took different kinds of scissile stone, divided almost imperceptibly into the thinnest layers, and, 1. I dipped one end of them into water, which after a little time crept up

between the layers, and rose spontaneously to the surface or top of the stone. 2. This was shewn still better by dipping the bottom of the layers in oil of turpentine. 3. The water rose still more rapidly when warmed. These results shew that both hot and cold water, and oil, will ascend between layers of stone by a kind of spontaneous effort, without any assistance from pressure. 4. Hence, on examining the strata of scissiles, we see everywhere in their contact that there has been some kind of fluid, either calcareous, aluminous, vitriolic, oleaginous, asphaltic or sulphurous, which had either stained the surfaces of the strata, or had formed an interstratum. To place this point in a clearer light, I subjoin some parallel experiments on the spontaneous ascent of water. 1. If two pieces of marble or glass be laid very closely together, and one end of them be immersed in water or oil, the fluid creeps upwards between the apposed surfaces and arrives at the top: as may be proved by placing bibulous paper between them. 2. The fluid rises rapidly and easily in proportion as the pieces are closely joined. 3. This experiment succeeds as well in a vacuum as in the air; according to that enlightened English authority, Hauksbee. 4. It is a well known fact, that water rises spontaneously in sugar, lime, snow, ashes, sponge, and all spongy bodies with small pores or passages. And in glass tubes, water rises above its external level in proportion as their bore is small; the sap also in plants, trees, branches, leaves, &c., follows the same law; gaining the tops, and moistening all the parts, and giving birth to fresh green foliage and beautiful branches. We may therefore conclude that water rises spontaneously between layers, or through passages of very small dimensions, and is not under these circumstances acted upon by gravity. Here, then, we have the cause of those numerous springs, which gush from the surface of the earth's crust.

This view is strengthened by the immense number of springs that come forth from one strata; to say nothing of those in foreign countries, which have been described to the learned world by different travellers. Thus we often find that, 1. Three or four kinds of springs issue from the same soil, or the same rocky bed. 2. And acidulous springs frequently exist near others of pure water. 3. Also hot springs near cold ones, as at

Aix-la-Chapelle. 4. Vitriolized waters impregnated with aluminous and metallic particles of various sorts, as at Liège, Spa, &c. But let us quit the foreign springs, and mention some in our own country. 5. In a very high mountain in Sweden, the Kinnekulla, a fountain of pure water springs from innumerable fissures in one of the strata. 6. There are similar fountains in Billingen, Hunneberg, Mösseberg, and other mountains in West Gothland, which are stratified to their very bases, and the water is often sufficiently abundant to keep a mill-wheel constantly going : water courses and small lakes are formed likewise on the very tops of the mountains. 7. At Rhyda in West Gothland, three different kinds of springs gush from one bed of soil; two of them are vitriolized in different proportions, and the third, in their immediate vicinity, is a spring of pure water; and all three flow through the clefts and fissures between the layers. Thus we find, both by experiments and from observation, that water rises upwards between the closest joinings of the flat surfaces of the layers, and through channels in mountains which nothing else could penetrate.

II. The second point to be noticed, is, that *fire may commence with a small beginning, and afterwards increase, so as to diffuse itself through bodies of immense size. And if covered up, it may last for centuries.* The diffusion of fire from a small beginning is sufficiently evident, as the greatest conflagration may arise from a single spark. It bursts out spontaneously in stacks of hay and corn. In a large and well-closed iron furnace it is diffused from a little charcoal throughout the whole mass of fuel; likewise through heaps of sulphurous and other stones; as may be seen throughout the mining districts.

That heat, when once kindled, will last for a great length of time in covered places, is shewn by the following circumstances. 1. In large iron furnaces, completely filled with charcoal, a little fire is introduced at the lower part, and the furnace closed up. In due time, the heat gradually spreads throughout the mass of charcoal, and lasts for a fortnight without much consumption of fuel; becoming more intense every day, and seeming as if it might exist for several months, if required. 2. In the furnaces used for making copper into brass, if the apertures be closed, the fire remains in the charcoal for several weeks,

without any great consumption of fuel; it is, however, converted into heat; that is to say, the colour of the fire is changed to black. 3. Fire well covered over with dust is placed beneath heaps of copper and other ores; when thus covered, it seems to spread in a circular direction, and will keep alive for six weeks. 4. In burning wood and trees for charcoal, fire is placed beneath them, and the heap is well covered up with dust; but although the fire is thus surrounded, it becomes diffused throughout the pile, and converting the substance of the wood into charcoal, will remain in a state of activity for whole months. 5. The same result takes place if live fire, brands, or pieces of charcoal are covered with ashes. Thus when the episcopal seat of Brunsbo at Skara in Upsal, where my right reverend and excellent father resides, was destroyed by fire, the heat was found to be retained in the charred timbers beneath the ashes for three months. 6. We likewise have instances of mountains of fossil coal and other substances having smoked for long periods after once being heated.

From these examples we may now proceed to consider the subterranean heat which causes the warmth of thermal springs; and we may argue that it will diffuse itself through a whole mountain from a very small beginning; *i.e.* from some commingling of sulphur, vitriol, iron, and water. These substances would prove quite sufficient for this result, especially in stratified mountains, where the diffusion would easily take place, according to the reasoning and experiments already adduced. These arguments also prove, that when heat is once shut up in these mountains, it may remain for centuries without being extinguished; but as soon as an opening is made, it breaks forth in flames.

That there is some sort of subterranean fire, confined however to the crust of the earth, is sufficiently proved by, 1. The existence of volcanoes which vomit flames, as Vesuvius, Ætna, and others. 2. Also of mountains which are occasionally hot and emit hot fumes or vapours. 3. Of others from which the hottest springs gush forth. 4. In many places calcareous stones are found to be converted into true lime, and whole mountains into chalk; strata of calcareous stone with siliceous matter still enclosed in them, scissile stones, shells, &c., are also con-

verted into lime in like manner. These facts render it impossible to deny the existence of a crustal fire sufficient to penetrate whole mountains, especially such as are lamellated or stratified; in which, after they have once been heated, the fire, provided it be shut up, may last for ages without any great consumption of materials.

We may now perceive, 1. How water will rise to the surface between the flat surfaces of the strata. 2. How heat commencing from a small beginning may be dispersed through various substances, especially if they are lamellated. 3. How when it is enclosed in them, it lasts without much diminution, unless it meets with an orifice. 4. And that, near the surface, stones may be converted into lime.

The *thermal heat* is a natural consequence of these facts; for water passing through the strata of hot mountains, will of course come thoroughly heated to the surface. And if a mountain has received its heat as already mentioned, it will preserve it for centuries, since there are no openings for its escape; and the water which passes upwards through the layers or joinings of such a mountain will necessarily be impregnated with its caloric, and produce a thermal heat.

Before we proceed to the qualities of the *thermal salt*, we will give certain experiments performed with the water of Aix-la-Chapelle at Borcet, which is reputed to be lighter than the water in the city. 1. It smells like sulphur mixed with moistened lime. 2. The taste is saline, as of a nitrous substance mixed with common salt. 3. With gall-nuts it turns yellowish green, but when we add spirit of nitre, the colour is greenish yellow, like the topaz, with a beautiful red layer suspended in the middle, and the fluid intensely green above it, but paler beneath. 4. M. Bregmal, who wrote on the waters of Aix-la-Chapelle, says that it turns milky with gall-nuts; but others allege that it turns black; this however was not the case with the water at Borcet, although it was boiling when poured on the gall-nuts. 5. With syrup of violets it becomes of a dirty yellow, which afterwards changes to a dirty green. 6. With alum it becomes milky, which appearance remains when a solution of nitre is added; but it becomes clear on pouring in a few drops of spirit of nitre. The solution of alum mentioned

above is not changed by adding vitriol. 7. With sugar of lead it becomes very milky, and is precipitated by adding white vitriol; the precipitate being white, but the supernatant water green. 8. With common vitriol it is at first rendered turbid, afterwards it forms a thick brown sediment which subsides by degrees; in two hours, the mixture separates into five parts; the vitriol yet undissolved lies at the bottom; then comes a yellow fluid, above which is suspended a thick brown mucilage; the fourth part is a limpid green liquid, and the uppermost is a turbid one. After a lapse of ten or twelve hours, both the upper fluids have mingled to form a yellow one; and this result takes place if either the common green vitriol or the white sort be employed, except that with the white vitriol the colour is fainter. 9. No change was produced by the spirit of sal armeniac, spirit of nitre, aqua fortis, spirit of hartshorn, solution of crude tartar, oil of tartar *per deliquium*, solution of red lead in vinegar, borax, gum arabic, ammoniacum, or other kinds of gum, or by the solution of lead in distilled vinegar. 10. With a solution of mercury in spirit of nitre it turned very milky; but with a solution of the same in aqua fortis, it merely became opaline, and though there was a milkiness, it was less than in the former case. 11. With a solution of copper, the green colour changed toward blue; by adding common vitriol, whilst the copper still remained in it, the colour was rendered dusky and turbid; but when the copper was removed, the vitriol, &c., fell to the bottom and turned black, whilst the solution above it became a beautiful green. 12. With sal armeniac no change took place, but by adding white vitriol it turned green. 13. Nor was any alteration produced by red lead dissolved in distilled vinegar; but on adding white vitriol it turned whitish. 14. It was not changed by borax, but on adding white vitriol, it became a pale turbid yellow, and at length the upper part turned a turbid green. 15. With a solution of camphor no change was produced, but on adding white vitriol, two opaque strata were formed, the upper one of which was beautifully opalescent, of a whitish blue, which some hours afterwards became pellucid. 16. It was not changed by gum ammoniacum, but it turned an intense yellow on adding white vitriol: this effect was also produced on adding the vitriol to a solution with

gum arabic. 17. With spirit of hartshorn it was not altered, but when aqua fortis was added, it became a beautiful and intense red, and for a long time gave forth small bubbles. 18. It would not mix with oil of linseed, almonds, or turpentine, any better than with common water, but, like water, became milky on adding oil of tartar *per deliquium*.

The sides and bottom of the passages, through which this hot thermal water flowed, were encrusted with a sort of tartar, which could be broken off in fragments. 1. The colour of this tartar was brown, and sometimes yellow, with small red spots or drops. 2. It was nearly as hard as stone. 3. It had no smell, and only a very faint saline taste. 4. It was violently acted upon by spirit of nitre and aqua fortis. 5. Distilled vinegar dissolved it with effervescence, and the solution was somewhat milky. 6. The solution in vinegar turned green with syrup of violets, but very yellow with gall-nuts. 7. When this tartar was dissolved in aqua fortis, it at first gave out fumes, and increased in volume, but afterwards the liquid turned green, its volume being much augmented. The solution in aqua fortis, when mixed with syrup of violets, was of a colour between green and red, and had a bitter sweet taste; after some time, it inclined to a turbid green, and deposited a substance of an opaline colour. 8. When the tartar was reduced to powder in the fire, it became of a grey colour, something like the deposit just alluded to. 9. A green vegetable growth had fixed upon the sides of these warm springs; the juice expressed from which exhibited no effervescence either with acids or alkalis, although with aqua fortis it gave forth a vinous odour.

From these experiments we may in some measure conclude, that the salt of this thermal water is principally calcareous. I performed a similar set of experiments on a solution of the salt of quick-lime; but they differed in this respect, that some kinds of quick-lime do not yield the same results as others; thus some turn milky with gall-nuts, some become yellowish green; whilst others assume an intermediate appearance between the milky and green.

Moreover, the following arguments seem also to prove, that thermal waters contain a calcareous salt. 1. In the neighbourhood of thermal springs, we generally find calcareous moun-

tains; some of them entire, some partly decayed and fallen into dust, and some partly calcined and converted into pure white lime, with flint embedded in it, either in pieces or in layers; whole fields, therefore, are scattered over with flints of different kinds, which were formerly embedded in the lime, but are now left bare. At Aix-la-Chapelle, I have seen even scissiles and layers of shells, and the very fish converted into lime; from which alone we may conclude that there was once a fire that penetrated the mountain, and calcined its superficial matter. 2. Thermal waters exhale sulphur; like quick-lime, when hot and dissolved in acids, as I have repeatedly experienced. 3. They also have the colour and taste of lime water; and tartar itself is calcareous. 4. The salt of these waters is extremely penetrating, and enters the nerves and bones, just like calcareous salt; which is also used in certain sympathetic inks, and effloresces from the surfaces of gates, walls, and the bark of trees. 5. It is well known that lime water possesses the power of softening hard and nervous swellings, almost in the same way as mineral waters; which also affords reason for concluding that a calcareous salt exists in these thermal waters; in others, a salt of a different nature; and in some, no salt at all; according as the water passes through the crevices of a mountain impregnated with a particular kind of salt, or the contrary, and heated by a fire of long continued burning.

MISCELLANEOUS OBSERVATIONS.

PART II.

On Vitrification, and the change of particles into Glass.

The following points are worthy of notice in the large iron furnace, in which the crude substance or ore of iron is first roasted. 1. When the scoriæ flow out of the furnace, they immediately harden, and scarcely come in contact with the air before they lose their fluidity, preserving however a degree of tenacity for some time afterwards. 2. Wherever the mass is thinnest, and soonest exposed to the air, as at the corners, edges, and similar parts, the scoriæ appear like pure glass, but this is not the case in the thicker parts. Thus the part which first congeals is converted into glass. 3. If a piece of cold iron be put into the furnace (as is frequently done by the workmen to separate the pure part from the impure), and then withdrawn, it will be found to be encrusted with scoriæ; of which those next to the iron will be converted into brilliant, pellucid glass; but those which are farther off will be ferruginous and dusky brown, and not at all transparent. 4. If a heated rod of iron be thrust in, instead of a cold rod, there is no appearance of vitrification around it. 5. When the melted iron is let out of the furnace, it is as white and bright as silver on the edges, or *ears*, as they are called. 6. This silvery colour is usually observed if the sheet of iron be thin, or in all the iron that first cools. 7. If the beds of sand, into which the iron flows, be moistened, (as is common in some places, especially at the furnaces of Helsingland and Oregrund,) the lowest part to the

middle of the mass is of this silvery colour, while the upper parts are grey and black. 8. The iron which has this colour is lighter and more brittle than the remainder. 9. We may then conclude that the particles of the scoriæ, and likewise of the iron, are converted into glass when they cool rapidly, whence this silvery appearance seems to be nothing more than the beginning of vitrification; but if the cooling take place gradually, so that the particles can arrange themselves in a different position, no vitrification occurs.

We shall briefly run over those experimental facts which are generally known. Thus, 1. Glass cools with great rapidity; and as soon as it is removed from the fire, it loses the fluid state and becomes tenacious. 2. It is very tenacious when hot, but very brittle when it cools. 3. It is pellucid, on whatever side it is examined. 4. It has about the same specific gravity as stone, and even although made from metal, still is much lighter than metal. 5. There are hardly any bodies but may be converted into glass. 6. Glass, therefore, seems to be the last effect of fire. 7. Glass cannot be reduced to its original principles, except by gold.

These data are sufficient to enable us to explore the nature of glass. Without data, conclusions are of no value. Now if from the above we may define what glass is, and describe the method of its formation, we should say that *vitrification is nothing more than the transposition of particles into bullæ, and the mutual conjunction of the same*. We may infer this from the data. For, 1. We find that substances cannot be converted into glass, except by a very great heat, and unless the particles be thoroughly divided into lesser particles, to admit of being easily transposed by the fire into any given form. 2. Matter becomes lighter when vitrified; which cannot possibly happen unless it swell out into bullæ, in which case the same weight occupies more space, and the bulk is increased, whilst the specific gravity is diminished. 3. Glass is transparent in every direction: which can hardly be accounted for, unless by a certain regularity in the form of the particles; and if this transparency exists on all sides, and the rays of light are transmitted in a similar manner in all directions, I believe that it is scarcely possible to conceive any arrangement of the particles better calculated to produce

this effect, than the bullular, which receives the rays from every side, and allows them to escape in a concentrated form. But if the arrangement were angular or prismatic, or altogether irregular, the rays would be broken, and other colours would be produced. 4. Vitrified matters, such as scoriæ, form glass, when cooled quickly, but not otherwise. The heavier particles of iron are in the same case; for sudden cooling prevents the particles from being ranged in any other position than that which they occupied in the fluid state. If, then, they are suddenly cooled by the action of air, water, or very cold iron, or by the thinness of the mass, the particles must preserve the same arrangement as they have when fluid, so as to be comparatively little disturbed from the regular position, and to display the transparency and all the other visible properties of glass. But if, by slow cooling, the particles are confused, and the lighter rise upwards while the heavier sink down, then the bullular and even arrangement is destroyed, and a kind of disorder is occasioned; and hence there is neither transparency nor any other peculiarity of glass, &c.

It appears that the same conclusion may be deduced from the nature of fire, which generally converts the surrounding particles into bullæ. Thus, 1. If there be more fire on the outside of any substance than in the inside, that substance is formed into a globe by the fire. 2. If there be more fire within the substance than on the outside, then the fire forms it into bullæ; as is proved by thousands of experiments, as, 1. By boiling water, which the fire converts into myriads of bubbles or bullæ. 2. And when this water passes into vapour, each particle of the latter is bullular. 3. When the scoriæ are flowing out of the furnace, their surface exhibits an infinite quantity of large bullæ, and all the appearance of great ebullition, caused by the powerful issuing of the fire, which produces visible and considerable bullæ. 4. When any metal, as tin, lead, &c., is calcined and stirred about for a long time, we find that it increases in volume, becomes white, and afterwards red in colour; and what is this but the swelling of the particles into bullæ? And while the bulk becomes greater, the specific gravity becomes less, the colour snowy white, and as the process ad-

vances, vitrification takes place, and the same body becomes pellucid and still lighter. 5. Hence also we sometimes see an infinity of bubbles in glass, and hence the inclosure of the same matter in the glass tears, as they are called.

This is still better shewn in those bodies which are most easily acted upon by fire. 1. When tartar, lime, minerals, and other alkaline substances are dissolved by acids, the solution forms an immense number of bubbles, which seem to be occasioned by the escape of the smallest particles enclosed therein. 2. When the fire acts upon light fluids, whose particles easily yield to it, as those of milk, we see that the whole volume swells into bubbles; and a similar result takes place when the same particles are churned into butter. 3. Other fat and also certain fetid liquids afford instances of the same thing. 4. This is still more plainly seen in the ley of which soap is made; it is produced from a lixivium of ashes, with an admixture of fat and common salt, from which the tenacity of the particles arises. 5. When this ley has been stirred over the fire for a long time, we see the whole of it converted into a bullular matter. 6. This substance is pellucid so long as it is warm. 7. It is also very tenacious, for if it be raised up, it falls down in tough pellucid sheets like glass; and if the broad side be uppermost, it forms an exact figure of a bent retort. 8. If a portion of this substance be placed in the cold air, nothing can be seen but an infinite number of bullæ. 9. But some of these bullæ are dissolved, and converted into a red or brown fluid, whilst others remain in their place, and are of a white colour. 10. On stirring this liquid, it crackles, and exhibits a degree of brittleness.

But when there is more fire outside the matter than within it, the matter is, as we have said, compressed into globes. This is seen, 1. When a metal runs drop by drop into the fire, a globule is produced. 2. Drops of glass in the fire also produce globules, such as artificial pearls, spherical lenses for the microscope, &c. 3. A drop of water or of mercury is formed into exactly spherical globules, both in the air and *in vacuo;* but as soon as the fire penetrates into it, so as to be more abundant in the drop than outside it, the latter is immediately expanded into bullæ.

These phenomena and data afford us grounds for thinking that vitrification is only a transposition of particles into thin bullæ; that is to say, into the most regular position, since there can be no arrangement of particles of so exact a form as the bullular and spherical. If now we institute a comparison between vitrification and the liquid mentioned above, we find, 1. That the whole of the liquid can be formed into bullæ. 2. And in this state it is fluid. 3. It is so very tenacious that it forms coherent sheets, and assumes the shape of a retort, when it either falls down, or when a blast is directed upon it from below. 4. If this liquid cools, some of the bullæ fall into their pristine position, in which they exhibit an entirely different colour, as is the case in iron; others remain in the bullular state, but if their arrangement and size be unequal, they become white or silvery in colour, as also does iron. 5. If by a very rapid refrigeration the particles can be kept in the same position, they have all the transparency of glass.

But since these conclusions have been drawn from only a small number of data, we may perhaps be enabled, when our facts become more numerous, to acquire a better knowledge of the forms of these particles; and if any enquirer can elicit them more clearly from other data, we shall consider ourselves greatly obliged by the information.

We will conclude these observations by stating the reason why the scoriæ of iron in particular, whilst they remain in the furnace, and as they are flowing out of it, throw up sparks, in great abundance and with considerable force, to a height of two or three ells. On examining these sparks, they prove to be nothing more than globular particles of iron, which are also frequently seen in the same shape on the surface of the scoriæ. The reason appears to be this; the particles of the scoriæ, or the stony particles, have passed into glass or bullæ; but not those of the iron, which as they sink down through the interstices of the bullæ, tend to impede and obstruct the passages through which the fire is escaping; so that it is no wonder that they are cast out by the power of the fire, or are carried to the surface as globules, and thus are separated from the more expanded and lighter matter.

On the softening of hard Bodies, and on the origin of Ætites, Belemnites, &c.

That soft bodies become hard, and are converted into stone, is a well known and indisputable fact; thus clays, bones, animals, especially those of a marine nature, shell-fish, vegetables, and other substances, have been found in a petrified state. But whether hard bodies soften, and decay like trees, is not as yet so well ascertained; nevertheless, I wish to offer some facts to prove that such is the case. 1. Stones of a large size have been observed inclosed in argillaceous scissile matter, and completely converted into an ochreous clay. That they were once stones was sufficiently apparent both from their external shape, and from the internal arrangement and texture of their particles. Five specimens of the kind may be seen near the monastery of the Chartreux at Liège. 2. At the same place there are whole strata of pebbles, all changed into the same sort of clay. 3. Near the harder strata, there are likewise other entire layers of this soft yellow argillaceous substance, exhibiting the same position of the particles, the same micaceous glitter, the same roughness, texture, &c. 4. In the neighbouring hard strata, which were divided into cubical blocks or pieces, each piece was evidently divided by coloured circles, some by three or even more, and the inner circle was of a yellow tinge, like the above-mentioned substance. 5. In some pieces the central part had already become soft, so that the very beginning of the softening process was sufficiently conspicuous. 6. In the other strata, which are also divided into cubical pieces, but of smaller dimensions, nearly every piece was observed to contain the rudiments of ætites, lying as it were in embryo; the whole of their internal substance was divided and even separated into globes or ovals, easily removeable in layers, and consisting partly of clay, and partly of bole, but the square external crust was hard. There was a considerable difference amongst them. Thus some had an empty space in the centre, which in other specimens was half filled with a yellowish bole; in the centre of others there was a hard substance, with a little scanty and soft bole surrounding it; in others, again, the cavity was full of yellowish

bole; but all those in which there was no bole contained soft yellow clay, &c. All these circumstances point to one conclusion, viz., that the hard matter is first divided into circles; that it then begins to soften, commencing at the centre, and proceeding towards the surface. Now I think that the origin of ætites may be deduced form these conditions.

I have likewise been informed, 1. That there are some springs which will soften stones. 2. And that marcasites, with one half bole, and the other half marcasite, are found in large calcareous stones. 3. A hard crust of a ferruginous colour is always observed around belemnites inclosed in limestone, especially in West Gothland, in the same way as around these rudiments of ætites; next to which there is yellow clay or ochre. These circumstances may serve to shew, that the limestone is corroded or eaten away, and that by these means the hollow is enlarged in which the belemnite grows. Hence it may be observed, that, *firstly*, there is some kind of liquid which penetrates into stones, and when it stops, eats away and softens the hard parts, as is proved by the circles. But what is this liquid? whether it be calcareous, aluminous, vitriolic, ARGILLACEOUS, pure or other water, cannot yet be clearly determined. The Hon. Robert Boyle, however, has discovered a fluid that penetrated stones and marble, and completely coloured them.* *Secondly*, these hard substances are converted into sand, clay, or bole; the sand and clay are generally yellow, and the bole is brownish: colouring, therefore, appears to be the first degree of softening; conversion into yellow clay, the second; into bole, the third; and the absorption and emptying the space, the fourth. *Thirdly*, the softening takes place where the fluid stops; as decay or rottenness occurs in trees; it begins first of all at the centre, and also in the layers or circles, whereby they become stained, and the liquid stops around them, and dyes them with circular lines of some colour or other. *Fourthly*, we find that water turns iron to rust; which often takes place in layers, the matter engendered being yellow; which shews that hard substances may soften by the inverse process to that by which soft bodies harden.

* This fluid communicated a beautiful red colour to marble, without at all injuring its texture or polish. See Boyle's Works, folio; London, 1744. Vol. iv., p. 223.—*Tr.*

Hard stone may also be converted into sand, of which we have an example in the sand-hill of Lousberg, to the north of Aix-la-Chapelle, in which nine layers of shells are visible. 1. In some parts, it has precisely the external appearance of a regular mountain; so that if we judged of it by the surface, we should declare that it consisted of the hardest stone, notwithstanding it is only sand. 2. Cubical blocks lie around, as if fallen down from some stratum of hard rock. 3. The internal structure of these blocks, and the graining of their particles, are the same as in hard limestone. 4. In some places nuclei and pebbles are found, embedded and softened into the same species of sand. 5. Also layers of shells changed into lime. 6. Some parts still remain hard. 7. And in another mountain, to the south of the city, there are strata of sand of all kinds of different colours, yellow, red, grey, white, blue, and black; they are generally parallel to each other, with interstrata, embedded stones, and belemnites converted into sand. It is, therefore, probable that hard substances may be converted into sand by the action of water, and perhaps also of fire, in the same way as some kinds of limestone are reduced to powder by dropping water upon them whilst they are hot.

Hard substances are also found softened into lime. Thus we observe, that, 1. There are chalk mountains, which are nothing more than mountains of calcareous stone changed into lime by the agency of fire. 2. A siliceous substance, of very irregular shape, is often seen in the middle of the pieces of chalk. 3. The strata themselves appear to be entirely converted into lime, with layers of flints passing through the midst of them in parallel rows. 4. Scissile stones also are found changed into lime, as at Aix-la-Chapelle. 5. And shell-fish, nay, entire strata of them. 6. In many places, the lime is in a pulverized state, as at Dahla, Schofde, and other places in West Gothland, where whole tracts consist of very white lime reduced to powder, and when the winds and rains have carried it away, the flints that were embedded in it remain behind. 7. I might also instance entire mountains consisting of *margenstein*, or stony marl, divided into fragments; and which seems to be a sort of lime, and affords another proof that stones may be softened into lime.

In the quarries or pits from which the lapis calaminaris is dug, as at Limburg, Stolberg, and other places, the evidences of a softening process are very clear. Thus, at Stolberg, 1. I remarked strata all around, consisting of pure fragments of calcareous and different other stones, as in the already-mentioned mountain of Lousberg near Aix-la-Chapelle, in which two of the strata consist entirely of pieces of lamellated stones. 2. I have sometimes seen similar strata cemented together by a harder stone, closely resembling the common grey rock; by which also the shells at Aix-la-Chapelle are concreted together. 3. Where the lapis calaminaris is dug, nothing can be seen excepting a brown argillaceous matter in irregular lumps, in which these calamine stones are concealed, and which crumbles down when touched by the finger. 4. The lumps are most irregular in point of shape, appearing corroded, carious, and decayed, like scoriæ with recesses, angles, and cavities in every direction. 5. Some are black, others red, yellow, brown, grey, or white; some are comparatively light, and others heavier; they are all embedded separately in this irregular ground. 6. On examining the side or bottom of the pit, we perceive most evident traces of the softening of the calcareous stones into clay, whilst the mineral constituting the calamine remains unchanged. 7. This is plain enough, not merely from the sides of these quarries, but likewise from the rest of the neighbourhood: but the reason why some parts have been softened, and others have formed calamine, is no less obscure than the manner of the formation of stones into ores, and of different other matters into hard bodies. At a future opportunity I will mention many other circumstances corroborating my views; but enough has been said for the present.

On the entrance of Liquids, as, for example, Water and Fire, into hard Bodies.

That water will penetrate into stones and other hard bodies, is generally known; and the manner in which this takes place, may, I believe, be elucidated by the following observation. If we take square blocks of sandstone from any stratum, we shall see, 1. Certain separate coloured circles at a distance from each

other. 2. In the first circle we have a ferruginous or brown hue; in the second the brown is lighter, then we have a green, and at length a muddy yellow; while the centre is of the same colour as the stone itself. 3. If the block of stone be exactly cubical or square, the circles are exactly round; if it be oblong, we have ellipses instead of circles; if it be of any other shape, we find again a different curve. 4. In like manner it has been observed of mountain nuclei, in the preceding remarks, that when the sides are square, the nuclei are round; and that when oblong, the nuclei are oval. 5. If the stony substance be hard, the distance between the circles is less; but when it is soft, like sandstone, this distance becomes greater. 6. An equal number of circles is observed whether the piece of stone be large or small.

To demonstrate from this experiment, that in point of force or quantity water enters into hard bodies in the subduplicate ratio of the distances, 1. Let Fig. 10 represent a square block with a circle formed in it by the entrance of water. Now if we consult geometry as to how a circle can be formed by water passing in through square surfaces, the following will be the calculation. 2. The centre is at *m*; whilst the water is entering, it must of course proceed from the surface *c* to the centre *m*, where it stops; hence the line *cm* may be taken as the whole distance which the water traverses in its passage into the stone. 3. Since the water surrounds this square stone on every side, it enters from all points; thus in a right line from *b* to *p*, and from *r* to *o*; which are equal distances. 4. But when it comes from *b* to *n*, and from *r* to *n*, a meeting takes place in *n*, and hence a doubling or combination of the water. 5. Unless the quantity of water be equal at every point, a circle with such distinct colours cannot possibly be formed; and therefore we have to prove that the waters arriving from *b* and *r* towards *n* are conjointly equal in quantity to the single stream of water from *c* towards *z*. 6. This may be seen if the influx takes place in the subduplicate ratio of the distances. Thus let the stream of water be from *c* towards *m*, where it stops; meanwhile, as it proceeds from *c* through *z* to *m*, it diminishes gradually, that is, inversely, as already stated; so that the proportion would be the same if it passed from *m* to *c* in the

square *mz*; in the same way, when it passes from *r* to *o* through an equal distance, the force in *n* is diminished to the degree to which it would be increased in passing from *o* to *n*, or as the square *no*; so also in passing from *b* to *p*, at *n* it is as the square *pn*. 7. Now the two squares *no* and *np* are equal to the square *nm*, which is equal to the square *mz*; and the same result is obtained in every other part. 8. Hence we may conclude, *firstly*, that water passing through square surfaces, forms circles, because its quantity is always equal at the points of meeting; and *secondly*, that the influx diminishes in the subduplicate ratio of the distances or velocities.

In a similar manner we ascertain that fire penetrates into hard bodies in the same or subduplicate ratio. Thus, 1. I selected a sort of calcareous stone, which was very hard, and when pulverized was violently acted upon by acids; it was likewise changed into a beautiful blue by vinegar. As this stone was of a deep black colour, it was exceedingly well adapted for my experiment, and therefore I divided it into square pieces. 2. I placed these pieces in a fire, and allowed them to be calcined, but in different degrees. 3. I then withdrew them from the fire before they were entirely calcined, that I might notice the distances to which the fire had penetrated, and I remarked that one of them had been rendered perfectly white by the heat, but that the calcination had not reached the centre. 4. The nucleus that was still uncalcined, seemed of a blacker colour, and was exactly round; but if the piece of stone was of any other shape than square, the nucleus would assume a different curve. 5. I performed a similar experiment with clays, which became yellow or red by the fire. 6. It is necessary that the fire should at first be gentle, and that the heat should gradually increase, and be equal on every side.

That fire, regarded as a force, penetrates into hard bodies in the subduplicate ratio of the distances, may be further demonstrated from the increase of the quantities of ore placed in the large furnace in which iron is first smelted. On this subject, the following points were noticed. 1. When the furnace was filled with large pieces of charcoal, the ore was at first placed in the middle, over the central line, about once in every hour, or rather from seventeen to twenty times during

the twenty-four hours. 2. On the first day, only five loads of ore are thrown in at once, for if the quantity be larger, it is not melted; on the next day, seven loads; on the third, nearly nine; on the fourth, ten; on the fifth, eleven; and so on, until on the fourteenth day the quantity is increased to twenty loads, which is the highest limit. 3. On the first day, the ore is only placed in the middle, or over the central line of the furnace; on the next day, at a little distance from the centre; on the third, at a greater distance; and at length on the sixth or eighth day, up to the very walls, and all around wherever we may choose. 4. If the quantity of ore placed in the furnace be increased too rapidly, as, for instance, to twenty loads within ten days, a loss of fusion is occasioned; for about the fortieth or fiftieth day, a sort of resistance arises in the fusion, so that the ore cannot be well melted, unless the furnace be somewhat cooled. These experiments satisfactorily prove that the great stone wall cannot in less than fourteen days receive the degree of fire answering to that in the charcoal; but by its coldness, it diminishes and tempers the fire which is in the charcoal itself, so that in the first days it cannot melt more than five, seven, nine, ten loads; and so on.

Hence it follows, as a general rule, that *the power of fire in hard bodies increases in the subduplicate ratio of the distances to which it penetrates.* If now the heat in the centre of the furnace on the first day equals five; on the second, seven; on the third, nine; on the fourth, nearly ten; and on the fourteenth, twenty; which are in fact the degrees of fire in the same times, the spaces of time are found to be equal; that is, from the first day to the fourteenth; but the increase of the loads (which takes place in the same proportion as the augmentation of the power of the fire,) is as their squares. For example, the squares of 5, 7, 9, 10, 11, and so on to 20, are 25, 49, 81, 100, 121, and so on to 400; or rather, since the quantity placed in the furnace cannot be so precisely observed, the numbers will be 25, 50, 75, 100, 125, &c., up to 400. The differences between these are equal in equal times, increasing by 25, so that at length on the fourteenth day it amounts to $14 \times 25 = 350$, or in practice to 400. Thus the times are equal when the power of the fire increases in the duplicate ratio. Experience also proves

how exactly the nature of fire obeys this rule, for if these proportions be not accurately followed, a loss of fusion is occasioned at a future period.

This rule is of great use, for by it,

1. We can ascertain the power and degrees of fire from the centre to the circumference, in whatever substance it may be employed.

2. Also the times and moments of its penetration into hard bodies, by the ratio of its power.

3. Its power in smelting furnaces, &c., and in the stoves used in houses; and the difference caused when the furnaces are square, round, conical, &c.

4. The power of fire in the melting of metals.

5. Likewise on ores subjected to calcination; during which the fire is observed to penetrate these hard substances, and to form a sort of round nucleus in the middle, as in the calx of copper ore.

6. Likewise on vessels, as of lead, which, if kept full of water, are not melted by the hottest fire. The reason of this is, because the power of fire in hard bodies can only be increased in the subduplicate ratio, and as the water prevents this increase, the lead cannot be melted.

7. In the same way, if a piece of very thin paper be wrapped round the lead, it is not burnt until the heat has thoroughly penetrated into and fused the lead; nor is the paper burnt, if it be filled with moist sand, or any other substance which resists heat.

8. In the same manner we ascertain the influx of water into hard bodies, as stones, which become soft in course of time, and give rise to ætites, and certain figured stones, &c.

9. Also the entrance of water into metals.

10. As well as into ores and calcined stones.

11. And the entrance of mineral and other exhalations into hard bodies, &c.

Observations on Cooling, or on the escape of Fire from hard bodies.

The following facts will shew the wonderful nature of fire, as well as the variety which it exhibits in its escape out of hard bodies; but unless we are acquainted with the texture and arrangement of the particles in hard substances, I scarcely think it possible for us to obtain a correct knowledge of cooling, or of the egress of fire from these bodies, as to its degrees, times and distances. For, 1. As soon as the scoriæ of the crude iron flow out of the furnace, they lose their fluidity, and on the surface their fiery colour also. 2. Glass is affected in a very similar manner; although both these substances retain their heat and tenacity for a long time. 3. A quantity of melted iron flowing from the furnace, became hard on the surface in less than a minute, so as to resist a thrust with a stick; but heat remained within it for twelve hours: this mass was two feet long, one foot broad, and three-fifths of a foot thick. 4. The thinner parts of the scoriæ and iron, such as the corners, thin layers, and dust, grow cool more quickly than seems to correspond to the proportion given in what follows: as may be seen in those particles which are transposed into another position, nearly that of glass. 5. The furnace itself can hardly become cool for thirty or forty days; during which time the heat passes through the wall, which it could not do at first, however intense the fire. 6. The coppery stone called *skearsten*, (which is nothing more than copper ore melted and but little purified, containing a large quantity of sulphur,) keeps its heat for six or eight days, although an equal weight and mass of iron grows cold in less than eighteen hours. 7. A mass of copper itself cools in less time than a mass of this kind of stone. 8. Ignited fossil coal is immediately extinguished in the air, though it preserves its heat; the case is the same with stones, either calcined or while calcining, and with other hard substances. 9. Wood charcoal preserves its fiery heat longer than fossil coal. 10. Wood charcoal, when lighted and covered over, loses its flaming fire only, but not its heat. 11. Softer bodies, when heated and well covered, are not easily extin-

guished, but keep hot for months and years; as charcoal inclosed in a furnace, or covered over with ashes, and as burning timber under the rubbish in conflagrations. 12. The fire contained in charcoal is not extinguished by the air, but augments and breaks forth into flames. This is seen when the heaps of wood charcoal are opened, for the heat contained in them bursts forth into a blaze; so that heated charcoal possesses a property of becoming ignited by the contact of air, very similar to that of quick-lime in being heated by the contact of water.

These facts shew us that no certain rule of cooling can be laid down, since the fire does not seem to escape from hard bodies in proportion to their compactness, mass, or substance; but according to the particular arrangement of their pores. The following points, however, are worthy of notice: 1. Flame is not a definite degree of heat, enabling us to decide as to the degree of cooling by its going out on the surface; for there may be flame or fiery light with either a small or a great heat; thus light may be present in cold bodies, and a very intense heat in those without flame, far more intense than the most brilliant fire; such, for instance, is the heat kindled by the burning-glass. Hence we may conclude theoretically that luminous fire is the tremulation of the igneous volume, or the undulation of the rays. 2. In the more porous substances, the fire on the outside of the particles escapes more rapidly, while that contained within them escapes more slowly; as in sulphureous bodies, carbonaceous scoriæ, and lamellated substances. 3. Fire gradually diminishes from the periphery towards the centre; *i.e.* in the duplicate ratio of the distances, reciprocally as its entrance into hard bodies; which follows therefrom. 4. Unless this ratio be observed in its efflux, the fire remains in the centre, and in a proportionate degree in the periphery also; hence when fire is closed up, it lives for a very long time; inversely as it enters: for unless the duplicate ratio be observed, it cannot enter with accuracy to the centre, as has already been stated. 5. Bodies of the same material cool according to their bulk and cubic shape. 6. The longer that hard bodies have been exposed to the fire, the less can it be kept in them.

But as rules cannot be laid down with exact precision, owing

to the difference of cooling occasioned by the difference of the pores, we can here only remark, *first*, that when heat is enclosed, it is preserved in substances for a long time. *Secondly*. It is preserved longer in a large body than in a small one. If we could discover the nature of fire entering into hard bodies, and escaping from them, we might, I believe, deduce from the knowledge many profitable indications bearing upon the calcination of bodies, as sulphurs, salts, and metals; and upon their fixity or volatility, during calcination; as well as upon the internal texture of their particles.

On the improvement of Stoves in Sweden.

I will describe the stoves in use in Sweden and other northern parts, for they differ in their construction from those of Germany, Holland, France, England, &c., and they maintain the heat on different principles. They are furnished with iron plates, by which the fire-box of the stove is closed, after the wood has been converted into charcoal and ashes, so that the heat emitted by the charcoal enters the apartment and fills it; whereby we are enabled to enjoy the heat of one supply of fuel for ten or twelve hours. This advantage induces me to describe them.

There are various ways of constructing stoves; but to make them as advantageous as possible, the following particulars must be attended to.

1. *The stove must be directed towards the centre of the apartment*, so that the radiation from the middle of the fire-place shall tend thither; if therefore we draw lines from the four corners of the room, they intersect each other in its centre, towards which the stove ought to look, and its rays to pass. For the more space the blaze of the fire occupies, the more heat is produced, and the more comfortable the light and warmth. But this is not the case if the fire looks towards the side of the room, for then the flame or heat is at once intercepted by a wall, and is not diffused so generally as by the central arrangement previously commended.

2. *The less the depth of the fire-place, the better.* The stove

FIG 11

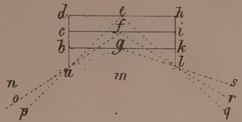


FIG.12.

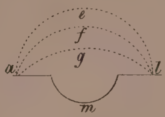


FIG.13.

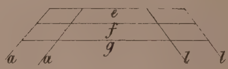


FIG.14.

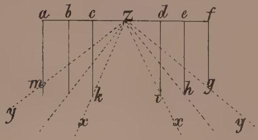


FIG.15.

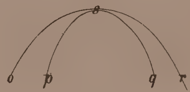


FIG.16.

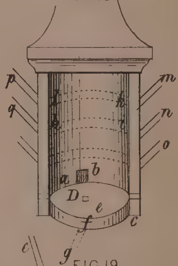


FIG.17.

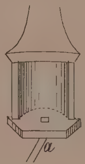


FIG.18.

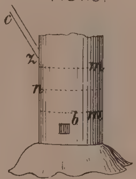


FIG.19

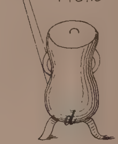


FIG.21.

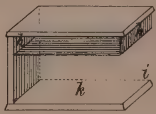


FIG.23.

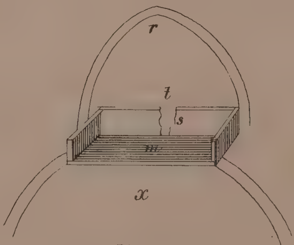


FIG.22

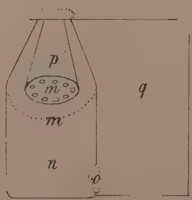
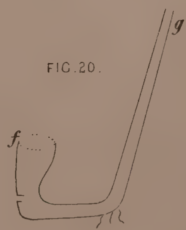


FIG.20.



may be either square or round, as in Figs. 11, 12, and 13; but let us first examine Fig. 11. The stove *adehl* is tolerably deep, and we find that the rays from the centre *e* pass by *l* to *q*, and by *a* to *p*, and do not occupy much space in the room. But if the depth be no greater than *acil*, more space may be filled by the rays; and still better, if the depth be less, as from *abkl;* the rays can then be largely diffused around, from *g* to *ls* and to *an*. A shallow fire-place, therefore, is better, and much hotter. By the same reasoning it follows, that from a deep fire-place, the rays at *z* (Fig. 14) are not diffused so much, and neither warm the walls and floor so well, nor present so cheerful a sight. If the fire-place be round, as in Fig. 12, and its depth reach to *e*, this construction will be most cheerless and sad, like what we constantly see in small country houses, in which also the rays do not tend towards the centre of the room. Hence, for the reasons just mentioned, it is better when its depth does not pass beyond *g*. In Holland and other countries, there is no depth, nor are there any sides to the fire-place, but only a back, whereby the fire may be enjoyed on every side. In Westphalia and elsewhere there is no wall at all, but the fire-place is in the middle: this is not the case, however, in Sweden, where the logs of wood are not put in layers, but piled perpendicularly; and there is no occasion to use either coal or turf.

3. *The wider the stoves can be made in front, the better.* Let Fig. 14 represent a fire-place of this form; if it be wide, as *afgm*, it diffuses the rays on all sides, from *z* to *yy;* if it be narrower, as *kcdi*, it scatters the rays less widely, as from *z* to *xx*. The same qualities exist in fire-places of a rounder shape, as in Fig. 15; in proportion as the anterior part is dilated, or the curve wide, or its sides are separated, as *osr*, the fire-place is better and more convenient than it would be narrowed to *psq;* owing to the same cause, since the flame can diffuse its rays more readily, and occupy more space, when the anterior part is wide, than when it is narrow.

4. Likewise, *the higher the stove can be made, the more space can the flame occupy on the ceiling*, and the more heat can penetrate into the walls.

By observing these four rules, 1, that the fire-place be not

deep; 2. that its sides be wide; 3. that it be lofty; 4. and be directed towards the centre of the apartment, in the same proportion we shall have the advantage of the blaze, and its rays will occupy a larger space on the floor, walls, and ceiling. Hence we remark, that a room frequently appears dull and cheerless, and we shudder at the sight of the fire-place, without any obvious reason; whilst sometimes, on the other hand, with as little evident reason, it looks most comfortable. The difference generally depends upon the construction of the fire-place. But care must be taken, in following these directions, not to engender the nuisance of smoke.

A new construction of Fire-place.

The following fire-place gives out more heat than that in common use.

Description. 1. Fig. 16 is a stove, D is the fire-place constructed according to the rules given above, and which may be either round or square. 2. It should be built of bricks placed endwise. 3. There must be a cavity within the entire stove, which therefore must be double. 4. *b* is a small opening, about eight inches wide, leading into this internal cavity just mentioned. 5. This cavity has three or four horizontal or perpendicular divisions, as *hi*, *lk*, where it is provided with a projection formed of a single brick, so that the heat may circulate from *b* towards *i* and up to *l*, and thus escape with the smoke into the chimney. 6. It is still better to continue this cavity farther, towards the sides *mn*, *pq*. 7. A draught may be formed by making an opening at *e*, communicating with the external air.

This stove possesses the following advantages:

1. It allows us to enjoy the blaze of the fire. On this account an open stove is considered preferable to a closed one, because the blaze is so cheerful, and the loss of it is not compensated even by the gain of increased heat. 2. Whilst the flames flicker, the heat diffuses itself through the wall or hollow side of the stove, first from without, and then from within, because the fire enters through *b*, and as the heat circulates

through its interior, the wall becomes very hot, and so continues after the fire goes out. 3. When the blazing ceases, the ignited charcoal may be pushed into the cavity through *b*, so that the heat will circulate throughout it, and penetrate the wall. 4. The greater the surface, the greater the heat; in concave spherical shapes, such as these stoves, there is a great extent of surface, because their walls are curved inwards, whereby much superficial extent is obtained in little space, and consequently in these stoves we may enjoy the comfort of a blazing fire, as in an open grate. 5. We can likewise have the advantages of a close stove; as after the flame has ceased, this stove possesses as much heat as a close one. 6. The heat can be maintained within the wall by a small charcoal fire, as may be seen in many places where the stoves are built with thin walls and a great extent of surface, in which the heat is kept up by sticks.

The circulating smoke ought to escape over the iron plate of the fire-place; an additional plate, however, is not required to shut its orifice, but the same plate which closes the fire-place will be sufficient. If it be pushed in a little farther, the other aperture can be closed at the same time, and therefore the same plate can be fitted to both openings by a greater or lesser insertion.

This new construction agrees in many respects with a newly-invented stove which a French writer has cleverly brought forward in a treatise called *Le Mechanique du Feu,* but it differs from it in the following particulars: 1. Our stove has an opening leading into the internal cavity, into which the embers can be thrust; whereby the wall may be heated twice as much as by the mere external contact of the fire. 2. When shut up, the heat radiates more abundantly from the walls. 3. No passage is required for the circulating air to enter, nor any orifice for the hot air to escape; because the fire-boxes in Sweden are generally shut up, as we have already said. 4. And this internal cavity can be extended as much as we please through the walls themselves; and the more this is done, the greater will be the heat.

On Wind or Draught Furnaces.

As wind furnaces are much used in calcining and fusing metals, as well as for domestic purposes, I shall briefly touch upon their construction.

The construction differs, according to the purpose for which the furnace is intended; but it must be observed, that, 1. The wind is attracted by the fire, as may be seen in common fire-places, whilst the fire is burning; we then perceive that there is a current of wind blowing into the flame, which afterwards becomes rarefied, and is carried upwards. 2. We see the same when a fire is lighted in the open air, as in the mines, in which cases we feel the violence of this wind, which comes against the bystanders in its course towards the flames. 3. Many persons have remarked that winds like miniature tempests arise during conflagrations. 4. In rude furnaces built with rough bricks or stones, the wind blows through the holes between the stones, and kindles the fire into flame. 5. If we make a communication between the external atmosphere and the fire-box of a stove, as at *a*, Fig. 17, as soon as the fire is lighted, the wind will rush through this passage and fan or blow the fire, and this wherever the passage enters into the stove. 6. In the furnace represented in Fig. 18, in which *b* is the entrance, and *c* the outlet, a very powerful draught is formed at *b* by only lighting the fire. The common or household stoves with bendings are generally constructed on this plan. 7. The same effect is produced when the furnace is like Fig. 19, in which there is an iron grating at *d*, and *e* is a pipe leading into the chimney, or through the window; and likewise in other iron stoves, which are used in many places, and have bent passages of different shapes. 8. Fig. 20 is an iron tube; there is an opening at *f*, and *g* is a pipe leading into the fire-box; the wind presses into the opening *f*, and drives out the smoke through *g*. The late Royal Plenipotentiary, Palmquist, made use of this contrivance, and took it with him on his travels. 9. When the fire-places are made with cross-bars, and with a space beneath, as in Fig. 21, the wind blows through the apertures underneath the fire, and assists the combustion. This construction may be seen in different places where metals are calcined, heated red,

and melted; also where vitriol, alum and common salt are evaporated; and in many other factories. There are many different shapes of these fire-places; but the oblong are most usual. 10. The fire-places are round in the furnaces in which zinc and copper are melted for brass. Thus in Fig. 22, *m* is the bottom, pierced with several holes, *n* is a round cavity, *o* is the door, *q* an empty space for the entrance of the air, which rushes through the conical furnace *p* with a very powerful draught. 11. Fig. 23 is on a similar principle, *m* is a grating, and the fuel is thrown in on two sides; *x* is a vacant place like a cell with two doors; above is a round, square, or other shaped furnace, as may be preferred: the wind at *x* rushed into the fire *s*, and drives it upwards with the blast, as seen in some glass-house furnaces, for example, at Liège. 12. I pass over many other varieties, which differ according to the uses for which they are designed; stoves for household purposes, furnaces for distillation, for metallic works, &c. I have only mentioned the preceding kinds as examples of the construction of wind furnaces, and I now proceed to the rules.

Regarding the *fire* itself, it follows from observation and theory, that, 1. A powerful blast is obtained, in proportion as the fire is large. 2. The greater the space occupied by the same fire, the greater will be the blast; thus if the fire be distributed over a broad bottom, more wind will rush in, and kindle it into flame. Hence the oblong fire-place is better than the square, and the square than the round, *i.e.*, if we wish the draught increased. 3. The more flame the fuel can produce, the greater is the draught, for the flame consumes the wind, and carries it upwards; hence a fresh quantity of air must always be supplied, which cannot happen unless the fuel be converted into flame.

As to the *passages* leading to and from the fire, it follows, that, 1. The draught is better in proportion as these passages are wide: thus if the orifice through which the wind enters, or that through which the rarefied smoke escapes into the atmosphere, be broad, the attraction and circulation of the air will be better and more free. 2. The more perpendicular they are, the better: those passages are the best which run straight to and from the air; for as the flame tends upwards spontaneously,

if it cannot escape in a perpendicular direction, it is forced out only by the pressure of the air beneath it. 3. The higher they are, the better; for flame or air rarefied by fire, tends upwards, consequently its mounting will be stronger if the passage is lofty; likewise if the incumbent wind comes from a high altitude. 4. The colder both ends of the passages are kept, the better; for the cold air rushing in, presses better upon the air rarefied by the fire; in like manner, in escaping, if the air be cold, the lighter volumes escape through it more easily, owing to the difference of weight. 5. The freest passages are the best. Thus it is better when the passage for the escape of the smoke, rarefied air, fire and heat, prevents them in no part from passing out freely: the same remark applies to the passage through which the air enters. For instance, the outlet must not be impeded by an opposite wall, by any confinement of the external air, or by the wind pressing upon it, and impeding the escape; in like manner the entrance must not be obstructed by a wall, or by closed doors, lest there should not be a sufficient supply of fresh air, owing to the obstacles with which it meets by the more powerful attraction of other places, whereby a deficiency in the draught must necessarily ensue; as may also be the case from other causes.

This may be illustrated, for example, by the furnace in Fig. 18. The orifice through which the wind must escape is at *z*, and it passes out better as the opening is wider: *mmm* are similarly circumstanced, and the escape of the air is facilitated when the passage *c* is more perpendicular; but if it be horizontal, the rarefied air does not rise spontaneously, but stagnates, or is only whirled about by the impulse. The greater the height of the smoke, the better; and the colder the air, the heavier it is, and the lighter volumes rise through it faster. The outlet *(c)* is likewise greatly influenced by the absence of impediments, by there being no opposing surface, no wind, no stagnant air weighing upon it, &c. The same remarks apply to those passages through which the air has to enter; the draught is better, as they are wider, more perpendicular, higher, cooler, and freer from impediments. But in this place I must be brief. Much explanation is indeed needed, but I shall endeavour to afford it when I treat expressly on different sorts of furnaces,

FIG. 24.

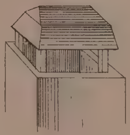


FIG. 25.

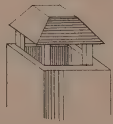


FIG. 26.

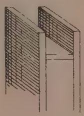


FIG. 27.

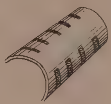


FIG. 28.

FIG. 29.

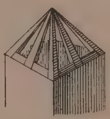


FIG. 30.

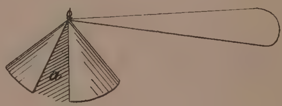


FIG. 31.

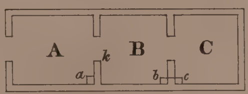


FIG. 32.

such as the various kinds of household stoves, metallic, smelting, calcining, reverberatory, distilling, chemical and other furnaces.

The causes of Smoke in rooms.

There are various causes why chimneys smoke into rooms; indeed the variety of causes is so great, that they are very difficult to ascertain: as, however, it is important to find them out, I have noticed the following particulars on this subject.

EXTERNAL CAUSES.

1. If the wind presses too much upon the outlet of the fireplace, the smoke will be driven into the apartment. This effect is produced, 1. By certain winds which blow more perpendicularly than others, for example, north winds. 2. If the wind be directed towards the outlet of the chimney by the wall, chimneys, or roof of the neighbouring house, or if it forms an eddy, the smoke is driven down into the apartment; consequently, it will not escape freely unless the outlet be carried above the top of the next house. To obviate these inconveniences, several contrivances have been adopted for the outlets of chimneys; some persons make the openings wide, for the wind to escape readily; others cover the aperture with poles, to protect it on two sides, as in Fig. 24. Others prefer the plan shewn in Fig. 25, and some that in Fig. 26. Some use bent coverings, as in Figs. 27 and 28. Some a sort of framework, like Fig. 29. Others make use of semiconical coverings, with a projecting plate like a wing, which is driven round by the wind. This is represented in Fig. 30, where *a* is the aperture, which is always on the opposite side to that from whence the wind is blowing: some persons change the direction of this cone by a small rope outside the house. Other inventors endeavour to provide a remedy for this annoyance in the interior construction of the chimney itself; 1. By leading the chimney obliquely upwards, or in a zigzag. 2. By enlarging or diminishing it above. 3. By making it describe a circular or spiral curve, like a turbinite, or spiral shell. 4. Lastly, some endeavour to correct the mischief by plates.

INTERNAL CAUSES.

The most general rule for curing the smoke, is, *to provide from some quarter a supply of air, to pass off through the fire-place, and carry the smoke along with it.* If this rule be properly observed, we shall command the chief source of this vexatious annoyance; for unless there be a current of air continually circulating through the fire and carrying off the smoke, there are, if I may use the term, no wings or vehicles to assist the latter in its upward flight. The wind that enters for this purpose, comes

I. *From chinks and crevices in the floor of the apartment.* For it is remarked, that when a fire is lighted, the air blows with considerable force through these crevices. Thus, 1. If they be closed, and there be no aperture elsewhere, the smoke frequently comes into the room. 2. Again, if the parts beneath the floor, through which the wind must enter before it passes through the crevices, be air-tight, the smoke is often forced into the room. 3. If there be any outlet for the air in the ceiling, or if there be a chimney in any adjoining apartment, it may happen that the wind which enters elsewhere through the crannies, will not pass out through the chimney of this fire-place. 4. Likewise when the wind does not press upon the lower parts, where it ought to enter, before it passes up through the crevices in the floor, a defect in the draught is occasioned.

II. *From the crevices of the windows.* If the air does not enter through the floor, it must come through the crevices of the window-sashes, and pass up through the fire, to carry the smoke with it. The smoke, therefore, may come into the room when an opposite state of things prevails; thus, 1. If these crevices be too accurately stopped up, and no others exist elsewhere. 2. If the chimneys in the adjoining rooms attract the wind which enters through the crevices of the windows. 3. If the wind does not press upon these crevices, but acts violently in the opposite direction; this cause, however, is but seldom capable of preventing the air from entering.

III. *From the crevices of the doors.* This is the most common source of the draught; especially when there are two or three doors opening into one room. In Fig. 31, ABC repre-

sent three rooms. Let us take the middle room B as an example, and we shall observe, that if the wind enters through the joinings of the door *k*, 1. The smoke may enter, owing to the room A being too well closed either by the door, windows and floor. 2. This mischief is rectified by partially opening a window or door in A. 3. If there be a fire in *a*, it may attract the wind before it arrives at *b*. 4. If the fire-place in *a* be of a better construction than that at *b*, that is, if it be higher, wider, &c., it may consume the whole of the wind before it can enter into *b*, and consequently, as the latter is deprived of its draught, it must smoke. 5. If there be a fire in the fire-place *c*, and especially if it be of a superior construction, and have a powerful draught, it may deprive the fire-place *b* of the necessary supply of air, and cause it to smoke. 6. The case is similar when there are doors in other situations, and we must ascertain in every instance where the air comes from, and whither it goes. When the chimney smokes, then, it is important to discover the cause. Thus we often find that it smokes when an adjoining fire is lighted, and not otherwise; or when a door or window is opened, or shut, in the next room. The cause should therefore be examined at once, in the following way. 1. In the first place, see whether the fault exists in the chimney itself, that is, whether it arises from *external causes*, and if so, remedy it accordingly. If there be no defect in the chimney, and still it continues to smoke, the cause must be *internal*, and must be sought for as such. 2. Try with a candle, or a very light leaf, or with the warm hand, where the air enters the room; whether through the crevices of the floor, windows, or door, or through more than one of these sources; but this examination must be made while the fire is alight, or it will not succeed, because at other times there will be no draught or circulation of air.

Having found the entrance through which the air comes, 1. If it be in the floor, see whether there be not a floor beneath, which may be air-tight, and thus impede the draught. 2. If by the windows, examine whether they shut too closely, or whether the external wind does not prevent the draught. 3. If through the crannies of the doors, see whence the air comes into the next room, whether through the floor, door, or chim-

ney, and then perhaps you may cure the smoking by opening or shutting them, as required.

The best cure for smoke seems to be by forming an aperture near *m*, Fig. 32, or elsewhere in the same horizontal line, and directed towards the inside of the chimney; this aperture should communicate by a tube with the external air in some part on the outside of the house, or under the floor. Then when the fire is lighted, the wind will continually enter through *m*, rise upwards through the chimney, and bear off the smoke with it; and this little orifice might be opened and shut by a small plate. Apertures of this kind are usual, but they are carried partly from the fire, and partly from the bottom of the chimney; the draught, however, will be better if the passage runs from the external air, and enters the front of the chimney.

A new construction of Air-pump, worked by Mercury.

It is well known that the air may be exhausted from glass receivers by a pump; but as I was considering the possibility of finding a more convenient mechanism than that in common use, I hit upon the following plan. In Fig. 33, A is a table, like that in the common air-pump: B is a glass receiver: *c* and *d* are two apertures with a valve fitted into each; the valve *c* allows the air to pass out of the receiver, and the valve *d* lets it off into the atmosphere. A hollow conical vessel E, made of iron, is accurately fixed to the under side of this table, in such manner that its cavity includes both the valvular apertures *c* and *d*. The portion *ff* is of leather; and the outer part *g* of the tube is again of iron, but very thin.

Operation. This machine is worked by pouring mercury through *m* in sufficient quantity to fill *ff* and some part of E. On raising the tube *g*, the mercury rises in E until it reaches the table of the pump, then, on depressing *g* below the level of twenty-eight inches, the mercury in E sinks, and draws off the air with it from the receiver through the valve *c*; on raising the tube *g* again, this portion of air passes out through the valve *d*; and thus the tube is alternately depressed and raised, until the whole of the air is exhausted. Under the table, at *z*,

FIG. 34.

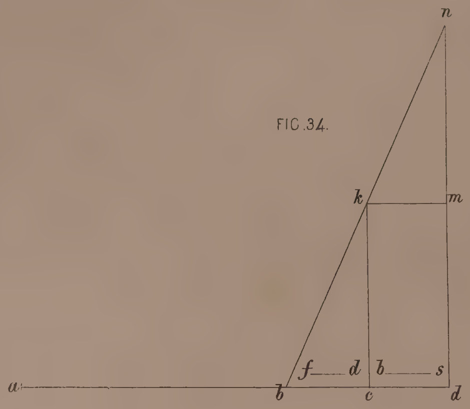


FIG. 33.

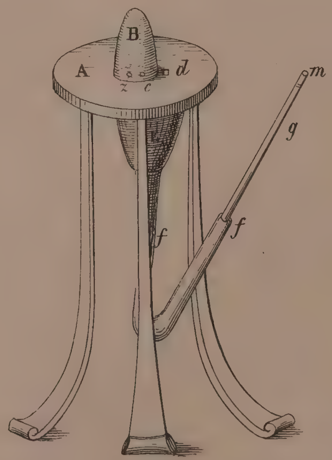
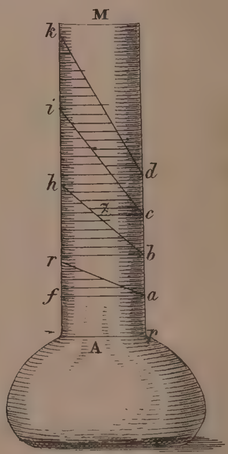


FIG. 35.



there must likewise be an orifice, opened by a screw, to allow the air to enter when required.

Remarks. 1. The more the tube g is depressed, the more is the air attracted. 2. When the air is pumped out, the tube must be lowered down more than twenty-eight inches, because such a height of mercury balances the column of the atmosphere. 3. When the air is readmitted, the tube must be raised up as far as d, which is indicated by the escape of a few drops of mercury through that valve. 4. In exhausting the air, be careful that the mercury does not fall below the iron cone E, leaving a vacant space in the leathern part f; for should this happen, the leather will be compressed, and the proper exhaustion impeded.

On the Salt Works on parts of the Swedish coast.

It is important to publish any facts that have occurred worthy of observation concerning the extraction of salt from sea water on the Swedish coast, for the following reasons. 1. Because certain persons wished to attempt this operation in the reign of King Charles XII., of glorious memory, who deigned to confer very ample privileges on the undertaking. 2. Also because very many of our countrymen, merchants as well as others, and as I have noticed, even the compilers of the *Acta Vratislaviensia*,* thought that the attempt would never succeed, because they saw that at first it was not successful, and they thought that it never would be. These causes induce me to state all that I know on the subject, especially as it has been my office to visit those parts of our shores which are best calculated for this purpose, and to propose the most eligible for selection. During my journey, I observed as follows.

I. The shores of the Baltic are not well adapted for salt boiling, because the water of this sea is very slightly impregnated with salt, on account of being towards the north, and diluted with the waters of the rivers, so that it scarcely contains a thirtieth part of its weight of salt, and still less at certain periods, as was ascertained by an instrument. Never-

* *Sammlung von Natur und Medicin Geschichten;* Breslau, September, 1717, p. 102; art. Neue Saltz Cocturen.

theless, the learned Helwig states, in his *Lithographia Angerburgica,* that salt is extracted from the waters of the Baltic in case of necessity; and in the year 1716, the attempt was made at Carlscrona, and the result ascertained.

II. On the shores of the German Ocean no greater success is to be expected, owing again to the small quantity of salt contained in those waters. This is the case, 1. About the straits of Helsingborg, where the water seemed to be too diluted, because it is mingled with that of the Baltic. 2. At Halmstadt, owing to the quantity of fresh water poured forth by the large river there. 3. The attempt was more successful at the city of Warberg, where the water was found to contain one-sixteenth of its weight of salt, especially in an island near the castle, where indeed the boiling of salt was commenced some time ago; besides which, in this place there is a good supply of peat or turf, well adapted for the purpose. 4. From Ondshall, as far as Gottenburg, it was unsuccessful, owing to the number of rivers, and especially that large stream Gotha Elf, which dilute the water too much to allow the salt to be extracted from it with any profit.

III. On the shores of the North Sea, from Gottenburg to Norway, I observed, that, 1. At Marstrand the sea was very salt, and many most convenient localities might be selected there; the boiling of salt had indeed been tried in this place by Count Frölick, but the attempt was unsuccessful, because unprofitable, owing to the high price of wood, charcoal, and turf. 2. But from Uddevalla to Norway, many places seemed highly suitable for the undertaking, and particularly at Gulmarsberg, where, *in the first place,* forests of considerable size yet remain. *Secondly.* An abundant supply of wood can be brought from Wermeland and Norway down numerous rivers which convey the best timber to the saw-mills; and an inferior kind of wood answers for evaporating the salt, such as the fragments and refuse from the mills. *Thirdly.* The quantity of peat in the neighbourhood might almost last for ever. *Fourthly.* The water is very salt, one part of salt being frequently obtained from seven to ten parts of water. *Fifthly.* The water in shore is very deep, sixty or seventy ells, and the saltest water may be taken from the bottom. *Sixthly.* Many salt works

have been established there, which are still in use; I counted twenty-seven of them.

IV. Salt boiling is common enough in the islands and places on the coast of the province of Bahus, especially near Stromstadt, in some of the bays and creeks of this sea, and above all, in the islands. Thus, 1. I enumerated twenty-seven pans or works for evaporating salt. 2. Formerly, there were still more. 3. But the number has decreased, partly in consequence of the ownership of the localities passing out of the hands of the country people, and partly because the wood could be sold to greater profit at Gottenburg. 4. In the province of Bahus, no other kind of salt is used either in cookery or in salting fish, than what is boiled on its shores.

V. The method of evaporation is very simple, but unprofitable. They have, 1. An oblong iron vessel, six ells in length, three in width, and about four-ninths of an ell deep. 2. This vessel is placed at a little height from the ground upon stones, so that the logs of wood must be placed close beneath it. 3. There is a chimney at the back part of it, for carrying off the smoke. 4. The water is pumped out of the sea, from a depth of five or six ells. 5. It then passes into a wooden canal, from whence it flows in a continual but small stream into the evaporating pan. 6. In the meantime the water in the pan is in constant agitation, and boils vehemently without intermission for twenty-four hours. 7. Until they have evaporated a large quantity of salt, which is in a crystallized state.

VI. The quantity of salt obtained within twenty-four hours, by the labour of one man, and the combustion of a pile of wood measuring three ells square, amounts to one ton, or four tons according to the Dutch measure. 2. The country people sell one such ton for a Dutch florin and a quarter. 3. Hence, no other kind of salt but the domestic is used in the whole district. 4. And it is astonishing that not one person in a thousand in this kingdom is acquainted with the fact.

VII. *Its quality.* 1. Its colour is snow white. 2. It is minutely granulated, like the Luneberg salt. Where the sea is not so salt, its colour inclines to brown. 3. It is used in that province for seasoning food, and for curing flesh, fish, &c., ex-

actly like the foreign salt; the inhabitants esteem it for these purposes, but the people in the neighbouring parts consider it as inferior. 4. It is, however, less fixed, and more soluble in water than the foreign salt.

VIII. *Defects in the process.* This method of boiling salt is faulty in the following points. 1. A very small pan is used, where one double or treble the size might be heated with the same cost of fuel. 2. The long and violent boiling greatly weakens the product, and deprives it of both its saltness and fixity. 3. No time is allowed for the salt to crystallize, consequently the granulation is small. 4. The skimmings are never removed; whereby its fixity is impaired. 5. It is not mixed with any foreign salt, such as the Spanish, or with any acid or other matter, which might assist its crystallization or fixity. 6. The water is not reduced and strengthened by the action of the sun, or of frost, wind, agitation, or motion, before the evaporation is commenced. 7. Nor is it pumped up from the deeper parts of the sea, and consequently it is lighter, and contains less salt.

IX. *Correction of defects.* These defects might be obviated, 1. If larger and more numerous vessels were used, as in Holland, Scotland, and Germany; whereby a smaller quantity of wood produces a larger quantity of salt within the same time. 2. It would be well to make the brine stronger by the action of the sun or by constant agitation, previous to being evaporated. 3. The brine can also be concentrated by freezing, for the pure water is converted into ice, but not the salt water: the celebrated professor, Doctor Roberg,* has treated upon this subject in my *Dædalus Hyperboreus*. 4. The salt becomes firmer, more fixed, and altogether better by an admixture of some other kind of salt, such as the French, darker Portuguese, or Scotch, as is practised in Zealand, Dort, and other places, where the darker salts are freed from their impurities by fresh boiling; and a considerable increase both in weight and profit is obtained. This increase of weight may be owing in some degree to a larger quantity of pure water in the crystals; hence, although these renovated salts are whiter, they are also weaker

* Professorens Doct. L. Roberg, *tanckar om Salts tilwerkande i Nordlånderne.* Dædalus Hyperboreus, Upsala, 1716, page 28.

and more watery, as proved by dephlegmation and distillation; on which subjects, the reader is referred to my *Principles.** 5. They are improved by adding a small portion of acid, and likewise by removing the scum. 6. And especially, by a proper method of boiling and crystallizing, which will be mentioned immediately.

From these facts it appears, 1. That the sea water of the province of Bahus is very salt, and may be evaporated for salt to great advantage. 2. In many places, circumstances are very favourable for the undertaking, and there is an inexhaustible supply of peat in those localities where wood is scarce. 3. By the help of art, and of proper boiling, good and fixed salt may be obtained, and in larger quantity, by employing different vessels and processes to those in common use, as mentioned above.

The reasons why this most important work has hitherto been unsuccessful, are, 1. Because at the time when it was attempted, the sea was infested by the hostile Danish fleet, and all the shores and bays were insecure. 2. It was afterwards neglected, because its noble originator, Christopher Polheim, was obliged to proceed to distant parts; and also, because the mercantile inhabitants prefer importing articles of this nature from a distance, to seeing any treasures the produce of their own shores. 3. We have therefore just grounds for believing that this work would be crowned with success, if it were carried on in a proper manner, and especially if the darker salts were purified at the same time, as is practised in Holland.

The method of purifying salts by repeated boiling. I shall here subjoin the method of purifying the darker and impurer salts, as employed in Zealand, Dort, and other places, with considerable profit. The French, impure Spanish, or Scotch salt, is purified in the following manner. 1. The water is brought in ships from the salter parts of the sea, and frequently from considerable distances, as for instance, from the sea to Dort; this sea water contains five *loths.*† 2. The impurer salt is dissolved in this water until it becomes impregnated with thirty-nine *loths*; which is ascertained by a piece of amber

* *Some Specimens of a Work on the Principles of Chemistry, with other Treatises.*

† The loth is nearly equal to half an ounce English.

floating on the surface. 3. This solution is then pumped into a very capacious round vessel, twenty-seven feet in diameter by three-quarters of a foot in depth, placed over a brick furnace of the same shape, but two ells high. 4. It is here evaporated with a brisk fire, and then skimmed. 5. The salt is left in this vessel to be crystallized by a gentle heat: the crystallization begins on the surface in granules like stars, which concrete together into a thin film, and then sink to the bottom. This continues until everything of a saline nature, as far as possible, has been deposited, and the whole operation is brought to an end within four days. 6. By these means a purified salt is obtained, very white in colour, and in largish grains; whilst its weight has increased from 2 to 3, and its value from 14 to 17. 7. The quantity obtained within these four days amounts to about twenty tons, with about two tons and a half from the sea water, which had been brought to the works; and the whole operation only required as much peat as would cost four-fifths of a Dutch florin in Holland.

There are many far more convenient places on the shores of the province of Bahus for purifying the impurer salts than in Holland, for, 1. The sea which washes the coast is so very salt, that it is unnecessary to bring salt water by ship from a distance. 2. Where wood is scarce, peat may be had in great abundance, and at a low price. 3. The iron required for the works is likewise cheap. 4. Besides, the workmen are accustomed to the business. Thus there will not only be the advantage afforded by the facilities and convenience of a port and a salt sea, but also a profit from the increase and purification of the salt.

A Method of ascertaining, by means of a Triangle, the individual Weights of mixed Metals, from the weight of the mass previously ascertained in Water and in Air.

The first method. Have in readiness weights, adapted for scales, of every metal and semi-metal; it will be sufficient to have weights of each metal answering to one, two, four, and eight loths, with one loth-weight divided into grains or smaller

parts. 2. Let us suppose that the alloy to be examined consists of copper and tin, as in cannon-metal, bell-metal, &c., and that we wish to ascertain the quantity of the tin. 3. Take such weights of copper and also of tin, (which weights should be ready, as we said above,) as to have three equal weights, namely, of the copper, the tin, and the alloy. Weigh each of these three in water; and first the tin; and observe how many loths and grains it weighs in the water: then take a corresponding number of divisions on a scale, and place them in a given line from *a* to *b*, Fig. 34. Then weigh the mass or mixed metal, and see how many loths and grains it weighs in the water, take as many divisions on the scale, and place them on the same line from *a* to *c*; then weigh the copper in the same way, and mark its weight from *a* to *d*. Take the weight of the mass in air, and a corresponding number of divisions on the scale, and place them on a perpendicular from *d* to *n*. 4. Next, erect a perpendicular from the point *c* to *k*, and from *k* to *m*, which may be done easily by parallels. Then, 5, *md* is the quantity of copper, and *mn* of tin. 6. On taking these lines with a pair of compasses, and measuring them on the scale, the divisions will shew how many loths and grains of copper and tin separately the mass contains.

The second method. If the weights of every sort of metal be not in readiness, it is of no importance, provided the weight of the alloyed mass be known; we will suppose, for example, that it is nine loths. As the specific weight of the metals is known, that of tin being to water as 7·3 to 1, we obtain 7·3 : 6·3 :: 9 : 7·767, that of copper being to water as 8·8 to 1, whence we have 8·8 : 7·8 :: 9 : 7·977. 3. Place these two quantities as before in the same line from *a* to *b*, and from *a* to *d*. 4. Put the mass in water, and observe how much it weighs; and place it in the same line from *a* to *c*. 5. Then proceed as before, to place the lines of the mass *ac* from *d* to *n*, and erect perpendiculars as before; the quantity of copper will be shewn by *md*, and that of the tin by *mn*.

Demonstration. Let the weight of the copper in air $=a$, and in water $=b$. Let the weight of the tin in air $=c$, and in water $=d$; and that of the alloyed mass in air $=e$, and in water $=f$. All these data may be obtained, either by calculation and

observation, or by weighing. Now let the weight of the copper in the mass $=x$; then the weight of the tin therein will $=e-x$. To ascertain by calculation how much this mass ought to weigh in water, we proceed as follows. Since the weight of the copper in air $=a$, therefore $a : b :: x : \frac{xb}{a}=$ the weight of the copper in the mass whilst in the water; in the same way, $c : d :: e-x : \frac{de-dx}{c}=$ that of the tin contained in the mass whilst in water, and their sum $=\frac{xb}{a}+\frac{de-dx}{c}=\frac{cxb+ade-adx}{ac}$. This sum must $=f$; consequently $f=\frac{cxb+ade-adx}{ac}$, or $\frac{acf-ade}{cb-ad}=x$, for the weight of the copper in the mass; and $e-\frac{acf-ade}{cb-ad}=\frac{ecb-ead-acf+ade}{cb-ad}$ gives us that of the tin; whence a proportion may be established between $\frac{acf-ade}{cb-ad} \div \frac{ecb-ead-acf+ade}{cb-ad}$, it becomes $\frac{a}{c} \div \frac{eb-af}{cf-de}$. Now the weights of the copper, tin and mass are equal, that is, $a=c=e$, according to the former proposition; hence e may be substituted for a and c, therefore instead of $\frac{a}{c} \div \frac{eb-af}{cf-de}$, it will be $1 \div \frac{b-f}{f-d}$; but the line bc in the figure $=f-d$, and the line $dc=b-f$. Since now the ratio of the copper and tin is as the difference bc to the difference cd, and the side nd is equal to the weight of the mass, and since we obtain the ratio md to nm as bc to cd, hence md and mn will give the weights in air of the copper and tin respectively.

The Glass of Archimedes; an instrument for ascertaining the proportions of mixed metals mechanically, without any calculation.

I have called this instrument the Glass of Archimedes, because we are indebted to that geometrician for the invention for weighing metals and recognizing mixtures by the increase

of the volumes. This method was discovered in the case of a crown of gold; but as it requires calculation likewise, I have contrived a glass by which the result may be obtained without any calculation.

Method of preparing the instrument. 1. Make a glass vessel like AM, Fig. 35, having a large cavity in A, and a tube of equal diameter throughout from A to M. 2. Fill the cavity A with water, wine, or any coloured fluid, as far as *pp*. 3. Take some loths of a metal, for instance, four loths of tin, and introduce it through M into A, and observe to what height the water rises in the tube; in this instance we will assume that it rises to *k*. 4. Divide the side *kp* into four equal parts, *ki, ih, hr, rp,* each of which denotes one loth. 5. Proceed in the same way with some other metal, for example, with four loths of copper, and observe again the point to which the fluid rises, which we will suppose to be *d*. Divide the side *dp* into four equal parts, each of which also denotes a loth: we have thus obtained the ascent of the volume of water for four loths of tin, and for four loths of copper. 6. Connect these divisions by the transverse lines, *ar, bh, ci, dk*. 7. Divide *ar* into four equal and parallel parts, *bh* into eight, *ci* into twelve, and *dk* into sixteen; that is, divide each part into as many drachms as are contained in the loths. The glass is now ready for use.

Method of using the instrument. Let us suppose that we have to examine an alloy consisting of copper and tin. 1. Let a certain quantity of it—for example, one, two, three, or four loths, as preferred—be weighed in the air; let us select two loths. 2. Fill the glass with water to *pp,* as directed above. 3. Introduce the alloy, and note how high the water rises, that is, to what division between *b* and *h*. 4. If the metal under examination were pure copper, the water would ascend to *b*; if pure tin, it would ascend to *h*, but as it is an alloy of both, the fluid rises to *z*. 5. The number of lines above this point shews at once how many drachms of copper the mass contains; and those beneath it, the drachms of tin. 5. For example, if the fluid rise to *b*, the mass is pure copper, and has eight drachms above it, up to *h*, which are equivalent to two loths. If it rise to *h*, the metal is pure tin, and weighs eight drachms, being the number of the divisions beneath it, or two loths. If

the water ascend to the third intermediate division, the metallic mass contains three drachms of tin, which are beneath, and five of copper, which are above the line. Or if it ascend to the sixth division above *br*, the mass then contains six drachms, or a loth and a half of tin, and two drachms or half a loth of copper.

In like manner if there be three, four or five loths, there are always as many divisions below, as there are drachms of the lighter metal, and as many divisions above, as there are drachms of the heavier metal.

If a larger instrument be required, as for pounds, make the space A more capacious, and the tube AM wider. Take four or eight pounds of metals, and try how high the water rises with copper, iron, silver, lead, &c., and divide this height into as many parts. 2. Join the divisions by transverse lines, and divide the first space into four equal and parallel parts, the second into eight, the third into twelve, and so on, as already described; each of these divisions will indicate four ounces. 3. Or if the first space be divided into eight, the second into sixteen, the third into twenty-four, the fourth into thirty-two, and so on, each division will then denote two ounces.

This method of weighing metals is preferable to that of weighing them in water and in air, according to the Archimedean principle of the increase of volumes; for the following reasons. 1. Because in our method it is of no consequence whether the water be heavy or light. 2. Whether it be well or river water, spirit of wine or oil, red or transparent. 3. But in the other way, it is necessary to know the weight of the water, otherwise a great difference arises from the difference of waters, seasons, heat, locality, climate, &c., which render the experiments somewhat uncertain. 4. It is best when the fluid is red, as it is seen more easily. 5. The interior of the tube should be rubbed with a little oil, to prevent the fluid from rising, as it generally does, to a greater height at the sides than in the middle.

Reasons shewing the impossibility of transmuting Metals, especially into Gold.

The idea of the possibility of transmuting metals, into gold especially, is deeply seated in many minds. The hope of effecting this conversion is encouraged by numerous stories and anecdotes, and by a flood of alchemistic writers, who having for long lost their time and pains, but perhaps found something which in their imagination was a kind of philosopher's stone, wished to teach others, by the darkest enigmas, to travel over the same road, and to allure them onwards, until they too, like their masters before them, had wasted their substance. This being the case, and as the extreme grossness of our vision prevents us from seeing more than the merest surface of gold, so we ought rather to determine the possibility or impossibility of transmutation by reason and experiment, than by ocular demonstration. In this course the following arguments occur to us.

I. Every metal has particles of its own of a peculiar form; silver has its own particles; lead and iron also; as proved by the phenomena of crystallization. Thus silver crystallizes in one way, iron in another, lead in a third. Every metal forms crystals corresponding to the shape of its particles. This is also proved by the very different tastes of different metallic solutions. The solution of one metal is austere; that of another is sweet; a third is exceedingly nauseous, of which mercury is an example; a fourth is very bitter, like silver. This variety of taste must surely result from the form of the particle, which, in proportion as it is pointed, impresses a varying sensation on the papillæ of the tongue. The same conclusion may be drawn from the diversity which occurs in the fusion of metals; from the diversity of their colour, compactness, and other properties; all of which demonstrate that the forms of their particles are very diverse. What therefore can be more beyond natural human power, than by means of some very subtle matter, actually to destroy the forms and intimate constitution of these metallic particles, and to transmute them into new forms, such as those of gold! for example, utterly to destroy the forms of the particles of mercury, to imprint upon them other forms,

and thus as it were to create gold anew by the mutation of particles. No one, indeed, will deny, that the particles of gold have their own peculiar form, which is more exact than that of any other metal. This is satisfactorily proved by experiments; for no metal preserves its own identity better, or is more self-similar, in all respects, in fire, in solution, in tenacity, in durability, &c., than gold; which shews that one particle is like another.

II. Another argument is that the individual particles of no metal are larger than those of gold, and consequently none are heavier. First, that no metal has heavier particles than gold, is manifest, 1. From the solution of gold by aqua regia; for gold cannot be dissolved by spirit of nitre or aqua fortis, unless sal armeniac or common salt be added to it: hence it is evident, that larger particles are required to effect the solution of gold than of any other metal; and consequently that the interstices and globes or particles of gold are relatively large. 2. This is also shewn by the experiment of compelling particles of hot water by hammering to pass through a golden vessel, that is, through the pores of the gold: the water at first passes through like sweat, and afterwards in streamlets; proving that the very interstices of the gold are larger than the bodies of the particles of water which pass through them. Thus the diameter of the particle of gold must be seven, if not ten, times larger than that of the particle of water. 3. We may arrive at the same conclusion from the great facility with which mercury penetrates a mass of gold, in such abundance as to change its colour to a snowy white, and with a little heat, to dissolve the gold away. 4. And likewise in some measure from the ease with which gold is melted, which may be owing to a particular cohesion. Therefore, since the interstices of the particles of gold are larger than those of any other metal, it follows geometrically that each of its particles is larger than the particle of any other metal. Hence the particle of gold, which is divisible by the action of fire or of a menstruum, is larger than the particle of any other metal, as proved from the size of the pores. How then is this form to be produced? What will enlarge the body of any particle, and imprint upon it the form of gold? Must not this be effected by filling the interstices?

III. Although the interstices between the particles of gold are so large, yet the weight of the mass far exceeds that of other metals. Each particle therefore must necessarily contain more matter, a greater quantity of the subtlest particles; that is to say, more substance to produce weight. The interstices are ample, but as they cannot increase the weight, the whole of it must be caused by the particle itself, in which there must be more matter than in the particle of any other metal. To transmute silver into gold, twice or even three times the weight would be required; and the same with lead. How then are we to obtain a matter so exceedingly subtle as to insinuate itself into each particle, and treble its weight? If we attempt this by menstrua, it is well known that gold cannot be dissolved by spirit of nitre, nor by aqua fortis, but by the larger particles of common salt, in which case the division is only into the large particles, as may be ascertained in a thousand ways. Still less has fire the power of volatilizing the particles of gold, for it scarcely divides them as effectually as the menstruum. Notwithstanding this, the herd of alchemists, by means of fire, would intrude into the particle of lead or mercury that most subtle matter, that cannot within myriads of degrees be dissolved by any sublunary fire: and still they think that the purpose can be effected by less than a farthing's-worth of pitch.

To these reasons we may add, 1. That as yet no transmutation into the less noble metals has been performed; how then can we expect to make gold, the noblest, heaviest, and most difficult of all? *O auri sacra fames!* 2. Mercury cannot be fixed by any other metal, but by sublimation it flies away in the quantity in which it was added.

We therefore conclude that art can achieve everything with metals, except to change the form and weight of their particles. As regards colour, it can be obtained by an admixture of other particles, or by the change of position produced by the action of fire or solution: for colour is nothing more than the determinate passage of rays through the particles, which if so arranged as to bend the rays entirely, at length produce a colour, either of golden, green, silver, or some other kind; and this, with a thousand varieties. In like manner, ductility and tenacity may no doubt be obtained in almost every sub-

stance by means of other particles; because those qualities depend upon the cohesion of the particles of matter. But to produce any change in weight and shape must be considered at the present, as in all past time, as an impossibility.

But it appears worthy of our pains to cultivate the art of separating metals with great exactness; of separating silver from copper, and gold from both, and other noble metals from dross, dirt, sand, and stones. And as it is certain that gold often lies in the bosom of copper, silver, clay, bole, and river sand, so art is required to separate it, which art is really noble and the true alchemy.

The Blood circulates through the Capillaries more easily than through the Trunks of the Arteries.

At first sight, it would perhaps appear, that the blood must circulate with greater difficulty through the minutest arterial ramifications, than through the large branches and trunks; for friction, and the various directions of the parietes of the vessels would seem to present more obstacles in the one case than in the other. It is well known that the course of the blood is from a wide trunk into narrower channels, which ramify into small arteries of imperceptible fineness, through which it at length passes into the veins, and back from the small vessels into the large, returning in a circle to the point from whence it started.

However, if we appeal to experience, we shall find that the blood will flow with much greater facility through such minute pores and tubes as the arterial ramifications, than through the larger and wider channels.

1. In trees and shrubs, which burst forth into new life every spring, we see that the nutritious sap rises by a spontaneous motion from the root to the summit: the tops of the loftiest trees are supplied with a larger quantity of moisture than the lower parts; thus the sap ascends of its own accord through the minutest tubes in the bark, and emulates the circulation of the blood in living beings. 2. If we fill a glass tube with ashes or any dry powder, which has minute passages between its particles, and if we dip the lower end into water,

we shall find within a short time that the water creeps upwards, and gradually moistens the ashes to the top. 3. A similar result takes place in glass tubes of very small bore; if the lower end of these be placed in any red or other liquid, it rises into them above the outside level, and to a greater height, in proportion as the diameter of the tube is less. This experiment succeeds as well in a vacuum as in the air. 4. Likewise if two pieces of polished marble, glass, or other substance are applied to each other, but with a sheet of blotting paper between them, and if the lower end of the pieces be immersed in water, the latter will be carried upwards between the plane surfaces and through the paper, nor will it stop until it arrives at the top: and the narrower the interval between the surfaces, the more speedily does this take place. This experiment succeeds as well with oil or spirit of wine as with water; as well in *vacuo* as in the air. 5. The same result is produced between the thinnest layers of scissile stones. 6. More clearly still in certain spongio-saline bodies, as sugar, different salts, snow, and calcined stones. 7. If a capacious glass vessel be half filled with brine, or a solution of common salt, and set aside to rest, the upper sides of the glass vessel up to the very rim will be gradually encrusted; so also, on pouring water into a moistened glass, some of the water ascends round the sides, which is especially seen if the fluid be coloured. 8. Again, this is still more evident in sponges, in which the water is carried upward spontaneously, and even better if the spongy substance be previously moistened; when the water will rise on the slightest contact with the sponge, and cause it to swell. 9. So also mercury enters into metals. 10. It follows, that water enclosed in a narrow glass tube will neither fall nor rise, but will remain passive.

From these facts it is manifest, that the blood circulates with greater facility through the ramifications of the arteries than through the wide trunks. In the spleen, in the lungs, and in certain membranes, we see nothing but the finest and most delicate arterial ramifications, together with a kind of spongy substance; and when the blood or lymph of the body enters them, it runs from one end to the other, as through a moistened sponge; *i.e.*, it runs from the arteries into the

veins spontaneously and passively, without any reaction or weight of its own, which is not the case with the blood in the trunks. Thus experience shews, that the circulation of the blood is performed more easily in the small than in the large arteries.

This is not the place to state the reason why fluids ascend spontaneously through fine pores. We may, however, observe that this effect seems to arise from the minuteness of the particles of water, which can creep up the sides in layers of such thinness, that they (the particles) cannot be disturbed by the air, or the subtler matter. Hence we see, 1. That water generally creeps upwards along the surfaces of glass. 2. When the fluid contained in a glass vessel is bounded by its edges, it is observed to stand higher there, and to rise obliquely up to them. 3. From the edges it slopes down towards the centre, and hence the froth tends to the middle of the liquor. 4. This is still more evident in the finer pores or passages, where water gradually creeps round the surfaces, and no column of air or ether can dislodge it: whence it may be demonstrated geometrically, that the fluid is driven upwards rather than downwards by such an oblique pressure. But these matters will be discussed elsewhere.

FIG. 36.

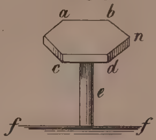


FIG. 37.

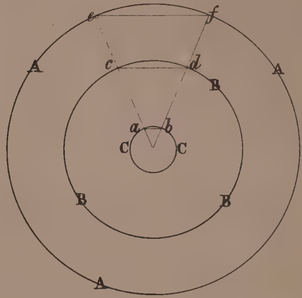


FIG. 38.

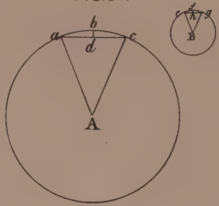


FIG. 39.

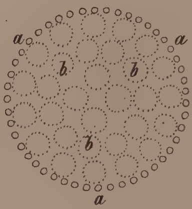


FIG. 40.

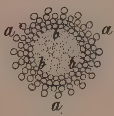


FIG. 41.

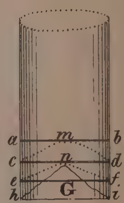


FIG. 43.

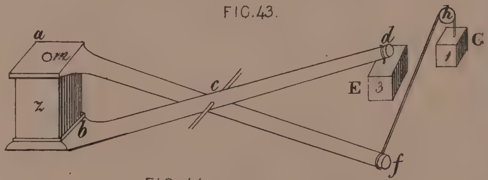
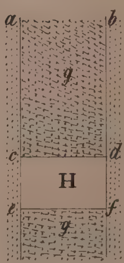


FIG. 44.

FIG. 42.



MISCELLANEOUS OBSERVATIONS.

PART III.

On a new germination of pure Water when converted into Ice.

THE industrious ingenuity of man has discovered several methods of forming artificial trees and shrubs, of gold, silver, mercury, lead, tin, iron, &c., and of astonishing the mind by certain most cunning feats of nature: but hitherto, to the best of my knowledge, no germination has been produced of only one metal, or of any single kind of metallic particles; thus no tree has been formed of gold alone, without the addition of mercury; or of silver alone, without mercury, tin, sulphur, &c.

Nature herself daily puts forth still more wonderful germinations from the bosom of the earth; and rears up in amazing diversity shrubs, trees, buds, leaves, flowers, fruits, and a thousand-fold play of objects, whose minute structure consists of salt, oil, spirit, water, &c.; principles which come over separately when plants are properly subjected to distillation. These cases prove, I think, beyond all doubt, that all growths of the kind derive their origin from the form, position, equilibrium, &c., of particles, and that there is nothing in them but occurs or is produced mechanically. If the particles of silver are reduced into their smaller constituents, and united with those of mercury, a crystallization resembling a tree never fails to shoot forth, and a similar result takes place with gold, tin, and iron; shewing that there is a peculiar union of the particles, which

assumes such an arrangement or position as corresponds geometrically to germinations.

I imagine that no phenomena are better calculated to afford us an insight into the mechanism and shapes of particles, than those of crystallization. But the difficulty lies in the great variety of generic particles contained in the crystallizations mentioned above. Thus, in the *Arbor Lunæ,* there are not only particles of salt and of nitric acid, but also of mercury and silver, and perhaps also of water and the subtle matter besides. Hence, from a single germination of this kind, we have the greatest difficulty in examining, or rather conjecturing, the mechanism and form of the particles. The same may be said of the crystals of any metal, in which the particles of the acid menstruum, precipitating salt, and also of the water, are mixed with those of the metal itself. Hence it is difficult to determine geometrically what may be the figure of each substance, and how the general form and effect are produced. So also in the daily growths of the fields, there are not merely acids, nitres, and essential salts, but various kinds of oil, spirit, water, and other substances; whose mutual combination, the individual parts being unknown, completely baffles the mechanician.

But as to water, although it be quite pure, and free from any admixture of salt, oil, or other substance, still every winter we find it crystallizing and germinating in definite forms. I will now therefore describe a new form of the kind, which I observed as I was travelling in the winter season in West Gothland, in Sweden, not far from the episcopal seat of Brunsbo.

I saw that certain aqueous germinations had shot forth from the ice. Among these there were several in the exact shape of hexagonal crystals; but from which they differed, as their upper plane was not oblique, and also inasmuch as they were raised by a round stem from their base on the ice. The shape is delineated in Fig. 36, where the side *ab* is longer than the side *dn;* *e* is the trunk, *f* the base or ice; the part above, *abcd,* is flat; the ice was covered with these productions, and as I was much surprised, I took up a number in different places, and found that they were all crystallized in the same form.

Besides this germination, there were several others upon the ice, which rose to a height of one or two inches above it; some

were like twigs, others like leaves, some stood upright like simple threads, others intersected each other transversely like lines, with a kind of sloping ridge. All these shapes, crystals, transverse lines, and other freaks of nature, may be seen in figured stones, whence we may in some degree arrive at a conclusion as to the production of such figures, which are frequently identical in the stones and on the ice. In winter, the panes of our windows are incrusted with a very delicate surface of crystallized ice, which frequently assumes beautiful forms, such as elegantly-curved stalks, bearing very sharp leaflets, like the fibres of leaves; and many other shapes artfully fashioned by the genius of nature and the mechanics of particles. The same phenomenon is exhibited by snow, which is nothing more than water congealed in the upper regions of the air; sometimes we find it in very thin flattened plates, but occasionally curled like leaves, sometimes in exactly hexagonal and star-like forms; or again, in globules, rough on the outside.

Since, therefore, we see that by the simple deprivation of fire, and consequently of motion in the interfluent subtle matter, the purest particles of water arrange themselves into these crystallizations, in which the forms, angles, and other qualities are manifestly geometrical, and especially since there is no heterogeneous substance to vary their texture and form, or to prevent the particles from assuming their proper forms; therefore it may be hoped, that by a skilful application of geometry the shapes of these particles may at last be discovered.

Let us only suppose, (as prejudices prevent us from asserting it more decidedly,) that the particle of water is round; and let us examine the geometrical combination of such particles, and we shall see most clearly the mechanism of the germination into hexagons, spirals, leaves, &c. Let us suppose, moreover, that the particles are rough; in which case they must necessarily be conjoined, when deprived of their interfluent matter.

A hypothesis of the figure and different magnitudes of Elementary Particles.

Nothing is more obvious to our senses than light, fire, air,

and many other similar elements of the world; but, on the other hand, nothing can be more unknown to us than the mechanism of their respective particles. It is, however, certain that different kinds of particles exist; that there are particles of air, particles of ether, particles of light, and particles in which the magnetic power consists; and that each kind moves uninterruptedly among those of another kind, so that air may be set in motion without any impediment from the particles of fire and light; and light, without being disturbed by other particles; and so on.

The following rules appear to be conducive to the knowledge of those secrets of nature which are involved in the natural mechanism of particles. 1. Let us assume that nature acts by the simplest means, and that the particles of such elements are of the simplest and least artificial form. 2. Let us take for granted that the beginning of nature is identical with that of geometry; in other words, that the origin of natural particles is due to mathematical points; just as the origin of lines, forms, and the whole of geometry: the reason being, that there is nothing in nature but is geometrical, and *vice versâ*. 3. Let us suppose that all these elements can be put in motion at one and the same time, and in one and the same place, and that each will move naturally without being hindered by the others. If we found our principles upon these three propositions as axioms, I believe that we shall be more readily admitted to an exploration of physics, in which there is nothing artificial, or opposed to the rules of mechanism; nevertheless the exploration necessarily presupposes that, 4. Established facts be taken as a basis, and that we do not stir an inch without their guidance. Of this we may be certain, that whoever attempts to make nature out of the figments of his own mind, and to arrive *a priori* at the knowledge of effects in the posterior sphere, in other words, to form infinite nature with finite imagination, must either be wise as a divinity, or embrace the deepest shadows of darkness for light.

Let us therefore assume, 1. That nature acts by the simplest means. 2. That the beginning of nature is identical with the beginning of geometry, or consists of points and motion. 3. That many elements exist in the same place, as air, ether, fire,

light, &c. 4. And that nature is to be investigated by the path of experiment. Let these propositions be granted, and let us shape our course accordingly. We now therefore suppose that air, ether, light, &c., consist of merely bullular particles, only differing in size; that is, that their diameters differ in the geometrical ratio of 30; thus, that the diameter of air being 1, that of ether will be $\frac{1}{30}$, that of light $\frac{1}{900}$, and so on. Let us suppose this as a mere hypothesis, the correctness of which we may doubt or deny, until we find that phenomena and experiments coincide with our position. The difference of dimensions is likewise only an assumption, which must be corrected by experiments, if the first or general position should hereafter be placed beyond doubt. Let us, therefore, examine this hypothesis according to rules, but only of the most general kind.

I. Reasoning from the principle of simplicity, I can scarcely imagine that there can be any simpler kind of particles than round bullæ. For, 1. They have no angle, save and except one infinite angle, comprehending all angles. 2. All the radii from the centre to the periphery are equal. 3. They have but one surface, and that a surface absolutely even. 4. Also a most perfect figure in which no inequality is found. 5. Therefore, since they possess the utmost evenness of figure, they also have the utmost equality of motion. 6. In a word, this form appears to be the simplest possible; so that if nature acts by the simplest means, she must act by particles of this shape. Consequently our hypothesis, which however I still call most completely in question, is confirmed by this argument.

II. If the nature of particles is derived from the same beginning as geometry, whence then does the line originate? Is it not from an infinity of points combined into length? And whence the surface, unless from an infinity of lines combined into width? Whence body, but from an infinity of surfaces combined into depth? The case is the same, if we suppose that in the beginning of all things, there were only mathematical points, without any shape, dimensions, motion, or geometrical attributes; and then suppose motion among these points. Here, however, the reader will object that no motion can be, until a surface or body be previously formed out of an infinity. I answer, that I take motion for granted; I assume

it, and suppose that it is a central motion of the simplest kind; for it cannot arise unless the points have first been combined into a surface. Therefore, in assuming motion, I assume at least a coherent or continuous surface—a surface to obey the motion. Let us then assume a minute bulla, according to the hypothesis; then amongst these bullæ, or new bullular particles, motion may be conceived, both central, progressive, and vibratory. I shall elsewhere shew in detail the nature and extreme velocity of the motion in the bullular particles. Therefore, if the central motion be given, the whole surface, or the infinity of points constituting the surface, must have a force from the centre to the circumference, which is of course bullular. But if the enquirer demands the cause of this motion, I tell him that no finite mind penetrates, or can penetrate, into this; for the first motion must clearly arise from the Supreme Mover, from the Supreme Life, from God, the Creator of all things, Who, by means of His primeval motion, according to our axiom, impressed upon His world of nature the identical principle that governs in geometry.

III. Our third object will be to ascertain whether according to this bullular hypothesis, we can account for so many different kinds of elements agreeing together in one place and at the same time without interrupting each other. In accordance with what has been previously advanced, let the diameter of the particle of air$=1$, and that of the particle of ether$=\frac{1}{30}$; then the ether can flow with unimpeded motion among the particles of the air, and run wherever any force impels it. Let the diameter of the particle or ray of light$=\frac{1}{900}$, as compared with air; or $\frac{1}{30}$, as compared with ether; then the particles of light will move and run in the spaces and interstices of ether, and much more so in the interstices or on the surface of air (as will be mentioned hereafter). In like manner a still more subtle matter may pass between the particles of light, and so on. Thus we see that one element will move in an uninterrupted stream between the particles of another, and move both centrally, progressively, and in vibrations; and that the two will jointly occupy the same place; this being proved by experience. Still however let this be considered hypothetical, and exceedingly doubtful, until every experiment that has been made, or

can be made, shall be found to coincide with the mechanism of our particles.

IV. But here perhaps the reader may demand at the outset, how particles of this sort can keep in their superficial position, and how the expanded bullular surface can move without laceration. But first tell me, 1. How the bubbles maintain themselves on the surfaces of fluids. 2. How soap bubbles can hold together and travel in the air for so long a time. 3. How vapours, which are bullæ, hold together, and, without bursting, mount to the upper region of the atmosphere, where they appear to unite into drops. Tell me the manner in which these effects can be produced so palpably. The following then are the reasons. 1. It is the nature of every element to press equally on all sides. 2. Therefore, when one element acts on the bullæ of another, the former presses from without towards the centre of the bulla, but the latter from within, from the centre to the periphery; and an equilibrium is produced. 3. Hence the particle of one element is maintained in its continuity by those of another, as by a chain constantly surrounding it. 4. Besides, it may be demonstrated geometrically, that the smaller bullæ are stronger and less liable to disruption than the larger, as we shall see hereafter.

V. Now should this hypothesis square with all the known facts of the nature of air, ether, fire, and light, as to their progressive, axillary, and tremulatory motions, as well as to their pressures and elementary signs and characters, we may then surely believe that it stands on a firm basis. But as each separate part of the subject requires a full explanation, I shall treat them one by one in succession. In the meantime our opinion may be considered as in the last degree uncertain, hypothetical and imaginary.

On the great power and intense motion of the smaller Bullular Particles especially.

Experience teaches us, 1. That when water is converted into bullæ or vapours, these remain entire, and rise without disruption into the higher regions of the atmosphere, although

the air presses upon them with great force on every side. 2. Water enclosed in a glass vessel and rarefied into vapours by fire, has force enough to break the glass, and even stronger vessels. 3. Water in the form of steam will set an entire machine in motion, for instance, a wheel, as has been ascertained both in large and small engines. 4. If melted iron comes in contact with a volume of water, the water is converted into steam, and acquires such power, that the iron is thrown into the air, frequently to a height of twenty ells; nor does the violent action cease until the whole of the superincumbent metal is ejected.

From these facts we may infer, that if air consist of bullæ, it possesses an immense power of resistance, and cannot be broken by any incumbent weight; still less can ether, if it likewise consist of bullular particles; much less can the rays of light, and other particles, provided they be bullæ of a still smaller size: for their strength increases in proportion as their diameters decrease, or as their surfaces increase to their diameters.

I have stated hypothetically, that the particles of the fluid elements, such as air, ether, light, &c., consist of a bullular surface only, that is, are merely bullular or superficial; and that those of one kind are so much smaller than those of another, that the former will move with facility and enjoy a fluid state in the interstices of the larger. For the present, let this be only a hypothesis, and now let us see what geometrical properties in point of consistence and motion there may be among particles of such a kind. It may be observed, that,

I. Bullular particles are firm and consistent in proportion as they are small; that is, the smaller bullæ are much more difficult to burst than the larger, either by motion or impulse, as may be easily demonstrated. In Fig. 37, let AAA be the surface of a large bulla, BBB that of a small one, and CC that of one of the smallest size. On subtending the same angle in all, namely, *ef*, *cd*, and *ab*, we perceive that its first subtense is greater in the large than in the smaller bulla, in the ratio of the diameters. Hence it follows geometrically, that the part *ef* can be more easily bent and driven in than the part *cd*, and *cd* than *ab*, owing to the decrease of size. Now since the points

of contact are subtenses of infinite smallness, let them be in the same ratio as the subtenses, and as the subtense of the same angle is greater in the larger than in the smaller circle, so it follows that if they move with particles of the same diameter, the larger will be more easily bent inwards than the smaller. We find also by experience, that a large glass globe is more readily broken than a smaller globe of the same thickness; so also, layers or plates equal to the subtense *ef* are broken with greater ease than plates of the subtense *ab*, since there are more points in the large body, as likewise follows from the nature of the lever. From this we conclude, that vapours are better adapted than large bullæ to maintain themselves in the atmosphere, and ascend to its higher regions without bursting; consequently air is better adapted than vapour, ether better still, and the rays or particles of light better still; and if there be a bullular element of greater subtlety, it will possess still firmer consistency, since the degrees of consistency are reciprocally as the diameters, or as the weights of the lever to the arms.

II. The central motion of the smallest bullæ is inconceivably greater than that of the larger, as follows geometrically from the same demonstration. When bullæ of the same magnitude move among each other, the central motion is rapid, in proportion as the points of contact are few; for these are what retard the central motion. When the smaller bullæ are reciprocally in motion, they have fewer points of contact than the larger. Hence we see the respective velocities with which the bulla of light, of ether, or of air, perform their central motions; and how greatly the flexibility or yielding of the bullular particles conduces to perpetuate the motion.

III. In the same ratio the tremulatory motion is most rapid in the smaller bullæ, and is as the squares of the diameters: In Fig. 38, let A represent a large bulla, and B a small one; let *abc* indicate the point of contact in the large bulla, or the distance to which its surface may yield and bend to the percussion of another bulla, so as to produce tremulation. Let *efg* shew the point of contact in the small bulla B. Here we see that if the larger surface *abc* be driven in towards *d*, the distance to which it is thus driven will be *bd*; but if, in the smaller bulla B, the surface *efg* be in like manner driven towards *h*,

this distance will be *fh*. By the laws of tremulation, or oscillation, the velocity of the motion will increase as the length of the pendulum diminishes, the increase taking place according to the squares. Hence, since the intorsion or distance *fh* is to the intorsion *bd* as the diameters of their respective bullæ, the tremulation from mutual impulse will be as the squares of the diameters: thus we perceive how incredibly more rapid is the tremulation in the smaller bullæ than in the larger.

Although our position is only hypothetical and doubtful, let us submit these matters to calculation, namely, that the diameter of the bulla of air$=1$, and that of light$=\frac{1}{900}$. Hence during a single vibration of the bulla of air, the bulla of light will have vibrated 810,000 times, which is a little infinity compared with 1; and in still smaller particles, the vibrations will be yet more numerous.

Hypothesis of the Undulation and Vibration of Bullular Particles.

I by no means intend at present to undertake the defence of the bullular hypothesis, but I only add to it the supposition that air consists of large bullæ, and ether, light, &c., of smaller bullæ. This is a mere supposition. However, I wish to know the geometry of undulation in these different particles. I define undulation differently from vibration. Thus undulation is the kind of motion seen in water when it is moving in circles, but vibration is the reciprocal concussion of each particle with those near it. The former is connected with a local motion of the particles, the latter takes place without a local motion of the whole particle, but is a yielding and repercussion in the bullular particle in a state of rest. Hence, vibration is subtler than undulation, and does not move the entire surface of the element; on the other hand, undulation is larger and sets the surface in motion, as water by impulse, air by sound. Now let air$=1$, ether$=\frac{1}{30}$, and light$=\frac{1}{900}$, this being merely our hypothesis, it follows that,

I. When the air vibrates, it cannot make the ether vibrate, because the diameter of the particle of air is thirty times larger

than that of the particle of ether. Hence, under these circumstances, the particles of air cannot strike a vibration in those of the ether, owing to the difference of size. Let A, Fig. 38, represent a particle of air, and B a particle of ether; let the vibration in the particle of air, by which its bullular surface is set moving, take place from *b* towards *d*: this distance *bd* we may consider as nearly equal to the diameter of the smaller particle B. Thus there is no proportion between the vibration of the particle A and that of the particle B.

II. But when the air vibrates, the ether may fluctuate and undulate; when the ether vibrates, an element with finer particles than those of ether may fluctuate, and so on. Thus the undulation of the lesser element is a consequence of the vibration of the larger.

III. Therefore when the air vibrates with sound, the ether undulates, and this undulation causes a vibration in the membranes of our sense of hearing. Hence we find that sound penetrates hard bodies, as stones, iron, and glass, through which air cannot pass. According, then, to this hypothesis, sound is a fluctuation or undulation in the ether, which can only arise from a vibration in the particles of air. Consequently there is no sound where there is no air.

IV. So likewise when the ether vibrates, the rays will undulate, and when the rays undulate, the ether will vibrate. Thus light may consist in the undulations of rays.

V. And again, when igneous bullæ tremulate, or fire is dilated into bullæ, the particles of light may undulate; the undulation constituting light. In a similar manner the vibration of light may give rise to an undulation in the particles of a subtler element.

VI. Moreover it follows, that the velocity of the undulation of ether is equal to the velocity of the vibration of air; and that the undulation of light is equal in velocity to the vibration of ether. This, I say, is a necessary consequence of our assumption. Nevertheless, we still claim for it no other title than that of a mere hypothesis.

Hypothesis of the Figure of the Particles of Fire and Air.

I am bound to give my views on these subjects only in the way of hypothesis, because all assertions regarding invisible things require to encounter many doubts, unless we should place an overweening confidence in our own opinion. As, therefore, I cannot assert, I shall only imagine or suppose; in order that in course of time, experiment may increasingly show whether my suppositions be in harmony with the truth or not.

According to our hypothesis, then, let the particles of air be bullular, with exceedingly minute particles of fire on their surfaces, as in Fig. 39 and 40, where *aaa* are particles of fire, very minute, and which we regard as not bullular, but round, and comparatively hard. But it may appear paradoxical to suppose that fire forms the crust of the air-particle, and at the same time a bulla, let us then consider the consequences of this assumption. 1. Let there be particles, similar to Fig. 39, on the surface of the atmosphere, where they are dilated, because there is no weight above them, to press them into a smaller space. Hence, in the highest regions of the atmosphere, on the tops of mountains, and above the clouds, we find that the air is very rare, and scarcely affords matter for respiration, or for supporting fire, and exhibits its usual phenomena in the poorest and thinnest manner: a great degree of cold is felt, flame is extinguished, menstrua do not act, and many other effects take place, according to experiment. 2. In lower situations, or under a certain height, these particles are more compressed, as in Fig. 40, and form a very thick surface or crust; for each particle is moveable, and one lies upon another, the pressure being equal on every side, according to the height of the column: hence they are compressed into a narrower space, and a thicker crust is produced. This view appears to coincide with experiment, for it is a well-known fact that air may be compressed by a weight, and it appears more compressed under a high than a low column, *i.e.*, at the bottom of the atmosphere. 3. There is less fire where the particles of air are more rarefied or distended: but more fire where they are more compressed, as indeed follows from the hypothesis. Thus in the same space, there is more

fire in particles like Fig. 40, than in others like Fig. 39. This is sufficiently attested by experience. Thus more fire exists in the bottom of our atmosphere, than in its upper parts. 4. From the above figure of the particles it follows, that in our sublunary world there can be no flame without air; this likewise is proved by experience, for a candle goes out when the air is exhausted, and sulphur and other highly inflammable substances will not ignite at all in the vacuum of the air pump; furthermore, flame goes out gradually in very high situations. 5. In proportion to the renewal of fresh air, the flame is increased, as indeed appears from the shape of the particle. Thus if the crust of the particle of air consist of igneous matter, it follows, that there is more fire when the supply of air is large, provided it be fresh. This is seen if we blow into the fire, or the flame is fanned by the wind, when it burns with new brightness, on account of the fresh accession of air. 6. It likewise follows, that if there be a volume of igneous particles, that is, an element consisting of pure fire, it ought by its energy to decompose other bullular particles of the same matter, in the same way as water divided into minute drops, which immediately unite by contact with a larger volume, to form a part of the same. This is in some measure proved by experiments on fire. Thus the igneous element seems to decompose the air, from which it derives food for augmenting its own bulk. Hence the air is spontaneously attracted by the fire, the wind blows towards the flame, to nourish and increase it; which I think could not be, except by a resolution of the aërial particles into fire, analogous to that of vapours into water. In the same way, fire resolves or decomposes sulphurous, oleaginous, resinous, and all other substances, whose inner cavities contain minute drops of the particles of fire. In fact they are resolved into the fiery volume by simple contact, in the same way as water divided into drops reunites into a volume. Hence we find that fire increases from a small spark as though of its accord, and feeds on air, sulphur, oil, &c. 7. As soon as a volume of igneous particles returns into the atmosphere, these particles are again formed into particles of air; in the same way as water is converted into bullæ, as soon as it escapes into the air, just as when it is changed into vapours. This is consistent with experience.

For as soon as an igneous volume rises into the atmosphere, it is dissipated and dispersed, and as it were formed into new particles that supply more heat than those of common air. 8. The aërial particles are expanded by fire; for since it is the nature of fire to attract and resolve the adjacent air, a rarefaction takes place; and this rarefaction gives rise to expansion, and the formation of a vortex by particles more or less expanded. This may likewise be deduced from the motion of igneous particles on the surface of air. 9. Fire cannot exist in pure air only, or where there is an abundance of particles of ether, without being at once converted into small bullæ, as is proved by experience. Thus we never see flame in air by itself, nor igneous volumes alone, without hard and very compact bodies. Wherever any cavity exists, the fire is immediately transformed into bullæ; or, to express it differently, as soon as the fire comes beyond the pores of hard substances, it appears to form bullæ, or new particles, which are large in proportion as there is space. Hence we find that fire will live in hard bodies, and remain in them for a long time before it goes out altogether: also that flame is nothing more than the fire in hard particles which are flying off, or in fumes. 10. In the same way we shall be enabled to show, that there is a greater quantity of fire in the centre than on the surface, in hard bodies than in soft; and other phenomena in accordance with the nature of fire. Nevertheless, as it may still be doubted whether all those particulars which are, or may be, known respecting fire, will harmonize with this view of the subject, so we will submit it to the reader as a hypothesis only.

On the interfluent subtle matter between the particles of Water.

We find that water possesses the remarkable property of great fluidity when it is warm, and of great rigidity when cooled beyond a certain period; in fact, that the same particles present the phenomena of solidity as well as of the greatest mobility. No one, I presume, can deny, that this change is owing to the presence of an interfluent matter; for as often as heat is applied,

the ice thaws, and its particles become fluid; as happens when it is placed over the fire, or during the spring and summer: on the other hand, whenever the fluid is deprived of its fire, the particles collapse into a fixed position. This fact amply proves that the fluidity of the particles of water is caused by some very subtle igneous matter of great mobility, interfluent between them, which separates them from each other, and prevents them from becoming fixed, holding them floating in its bosom in a state of suspension, and communicating its own mobility to them. This igneous matter also acts in a similar way upon the hard and more uneven particles of metals, whilst in a state of fusion; the difference between their fluidity and that of the aqueous particles being only one of degree. We shall see hereafter, from the same hypothesis, what kind of particles are interfluent between those of water and of the metals; experiments prove that these particles are but a peculiar matter.

1. When we inspect a piece of ice, we perceive that it is full of vacant spaces, apparently like globules, varying in size from a pin's head to a pea. They are arranged in a continuous series like spires, or little chains, and occupy nearly a fifteenth part of the mass. This appearance may be seen in any ice, except the icicle. Hence we may conclude that this subtle matter, whatever it be, is collected by the cold into granules or little drops, and leaving the spaces between the water particles, thus deprives them of motion and fluidity.

2. These concatenated empty spaces generally run perpendicular to the ice. For the element has the property of running into drops, when the little particles touch each other; just as takes place in water, when drops of it come in contact; also in oil floating upon water, in air, in certain barometers, &c. In like manner, this element combines into granules when fire and the solar rays are absent.

3. When water is frozen, we find that as much vapour exhales from it as when it is hot, if not more. This indicates that the interfluent matter flies off in the cold, and carries away the water in the vapour. What the nature of this matter is, we shall, God willing, set forth hereafter.

The mechanism of Bullular Particles.

Unless the mechanism of bullular particles be identical with that of elementary particles, the whole bullular hypothesis must fall to the ground. Let us see, therefore, whether the phenomena of the elements will harmonize geometrically and mechanically with the hypothesis of round particles. Let us then suppose that the elementary particles are round, those of water incompressible, those of ether compressible, and those of air consisting of igneous particles, as previously stated. And now let us inquire into the mechanism of such particles: let us figure to ourselves an ocean or lake filled with them, and that they are large enough to be visible. Now then let us apply geometry, by which, if it prove to be the same as in the mechanism of the elements, some doubts will perhaps be removed, and our thoughts be not a little cleared. But unless all the phenomena coincide with the view that we have taken, it is unworthy of any other designation but a hypothesis; nay, I will not bring it forward even as this, without adding that it is a hypothesis of the most questionable kind. Let us suppose, therefore, a place or reservoir full of these round and bullular particles, with a bullular and highly compressible ether in their interstices. Now it will follow from these mechanical conditions, that, 1. Every individual particle will run and be moved in its own place; that is, a particle of air will move upon its centre because it is round, and all the radii from the centre are equal, and there is no angle to hinder its gyration. When these particles move, there will be no upheaving or displacement of those near them: hence each particle, owing to its even or equal figure, enjoys an equality of motion, as indeed is clear in the element itself. 2. A volume of such particles is very fluid; owing to the mobility of each particle separately, and to the interfluence of the highly mobile particles of ether. 3. They are extremely mobile under the greatest weight; as for example, the particles of air at the bottom of the atmosphere, and those of water at the bottom of the ocean. 4. Bullular particles vibrate as well as undulate mutually; for since they are bullular, and the interfluent particles of ether are yielding and compressible, the re-percussion of one particle becomes that of another, the undulation of the one

is also communicated to the other, owing to their mutual and constant contact. This is a consequence of the undisturbed motion or spherical shape of each particle. The same phenomenon is observed in this element. 5. Bullular particles are rapid in motion in proportion as they are small and yielding, like those of ether: that they are also strong and resisting in the same proportion, has, I think, been demonstrated above: we find that the same is the case in the elements. 6. These particles are pressed by the height or column of the superincumbent particles: this is a mechanical consequence, for as each particle is moveable in its own place, and can be separated from its neighbour, it follows that the upper ones will press upon the lower, and these again upon the lowest, according to their depth. But the case is different, if the separate particles cannot move in their own places; for one will then be raised from another in mutual entanglement, so that the ratio of pressure is no longer according to the depth, as may be seen in heaps of rough stones, in sand, and in buildings. But round bullæ, which are moveable separately, will act as we have stated. Now, again, we see the same in the elements. 7. Such particles press and are pressed equally in every direction, according to their altitude, which is also a result of the mobility of the individual particles, and it may be demonstrated geometrically how a volume of such particles is pressed on every side, and the pressure runs in a circle. Something similar may be observed in the elements. 8. A kind of horizon is preserved on the surface, and the particles do not go there in heaps, as we know by experience, and as follows from their equal pressure according to their depth. Again, we see the same in the elements. 9. It is from these principles that the pressure is according to the size of the base. 10. We have already shewn that there may be vibration among particles of this nature. 11. If we assume that the position, form, and nature of the particles are bullular, we can refer their undulation and reciprocations to the centre, their angles, round surfaces, risings, depressions, equality of distances and times, the plurality of undulations in one place, and their greater or less concordance with each other, and many other properties, to geometrical principles. 12. It cannot be denied that the con-

ception of a volume of such particles will include the notion of transparency; for the light is nowhere broken by them; it does not go out or in through any prisms, cubes, or angles; it is not forced to alter its rectilinear direction anywhere, but enters and quits all the particles as if they formed one surface, and thus necessarily enjoys a regular passage and pellucid way. But as soon as the particles become angular, and of a prismatic, oblong, or other shape, the ray is forced to pass out by a different way from that by which it entered. The truth of this observation may be seen in large bodies, for when the most transparent substances are divided into unequal parts, and reduced to powder, they at once manifest colour: which phenomenon again fully coincides with the elements. 13. It is beyond doubt that nature is most simple, and acts by the simplest means: and there is no simpler figure than the spherical. 14. If then we choose to devise hypothetically particles of other forms, sinuous, serpentine, spiral, or fibrous, I confess that the notion will be deservedly ingenious, the inventors worthy of great praise, and their inventions cordially to be welcomed, if they can be referred to mechanical principles. For my own part I dare not yet advance this bullular hypothesis as genuine, for it is difficult to strike out any genuine novelty of undoubted truth regarding invisibles. Doubt must always attach, unless all the data that we possess at present, and all that may be discovered in future, coincide mechanically with the hypothesis; or unless an ocean of such particles, large enough to be visible, can be formed, and it can be shewn geometrically that they have the same properties as invisible particles of the same figure. There is still an infinity of data with which we are unacquainted; therefore I submit this opinion as a hypothesis, &c., &c.

On the centripetency of Heavy Bodies in elements consisting of Bullular Particles.

That an element presses according to its depth, and equally on all sides, upwards, downwards, and obliquely, is plain enough from experiments, as well as from the mechanism of particles,

where each is separately moveable in its place, which may be conceived in an element of bullular particles, as shewn above. Let us therefore suppose that each particle possesses mobility, and consequently that the pressure is equal on all sides according to the depth; we maintain that the descent of the heavier, and ascent of the lighter bodies, may be conceived mechanically, as follows. 1. Let *g g* (Fig. 42) be an element. 2. Let H be a weight, greater or less. 3. The element presses on this substance according to the height of its column *abcd.* 4. But beneath, according to the height of the column *abef.* 5. Here we see that the pressure upwards is greater than that downwards, that is, the column which presses upwards is equal to the weight of the elementary column *abef,* whilst the pressure from above downwards is equal to the column *abcd.* 6. Hence the difference of the columns, or the part *cdef,* cannot remain in equilibrium, unless its weight is equal to that of a similar volume of the element. 7. If, therefore, its specific gravity be greater, the volume *cdef* will tend downward, for the pressure of the lower columns *ef* cannot raise it, by the difference between it and the higher column *abcd;* if, on the contrary, it be less, it rises upwards, because the pressure of the upper column, together with the weight *cdef,* cannot resist the pressure of the column *abef.*

This result may be better seen mechanically, by two levers. 1. Let there be two levers like a pair of forceps *ab* (Fig. 43), meeting in *c,* and diverging towards *d* and *f.* 2. Let the weight E hanging from the lever *d* equal 3. 3. Let the weight G hanging from the lever *f* by a string over a pulley, be equal to 1. 4. And within *ab* let there be another weight equal to 2; so constructed as to be hollow, and to allow mercury or any other heavy substance to be poured in through the aperture *m.* 5. If therefore the weight within *ab* equal 2, the levers will be in equilibrium, for as this weight presses upon the plate *b,* together with the weight G, which is equal to 1, they are conjointly equal to 3, and the balance is kept in its place without either ascending or descending. 6. If mercury or any other heavy body be poured in through *m,* so that the weight becomes more than 2, there is immediately a greater pressure upon the lower plate, which consequently sinks. 7. If a part

be taken away, so as to reduce the weight below 2, it immediately presses on the upper plate, which rises. 8. A similar result takes place in the element, in which the pressure is equal both upwards and downwards: if then the weight contains more matter than is equal to the difference of its pressure, it sinks; if less, it rises.

If now an element and a surface be conceived, in which the particles rest one upon another, and are separately moveable in their places, and the surface is either circular or plane, it follows, according to the laws of mechanics, that in such an element the lighter substances will move upwards, and the heavier downwards. Thus, if the body suspended in the element contain more matter or compactness than an equal volume of the element itself, it will have a downward tendency. This however only occurs in those elements which have their own surface, and are so constituted that one particle lies upon and presses another. Under these circumstances it takes place immediately, according to the base and height of the column by which the pressure is caused. But should the reader wish to learn how such surfaces are formed in the vortices of the planets, and around bodies in motion, he must consult that physical searcher, and star of the learned world, Sir Isaac Newton, to whose researches all other investigations cannot but be inferior.

The notion of a Central Fire.

The opinion has been very prevalent that the nucleus or interior of the earth is hollow, and filled with a peculiar fire; and this has been attempted to be proved by the following arguments. 1. The earth appears to have been at first a star, which in process of time was encrusted, and formed a planet. 2. The earth is balanced in the solar vortex, which seems to be owing to an internal vacuum, whereby the crust might be balanced like a hollow globe of metal. 3. There are many volcanoes in existence at the present day, and formerly they were still more numerous: furthermore, there are thermal springs and boiling waters gushing from the bowels of the

earth. 4. Minerals are formed, and metals, and many substances undergo various changes in the bosom of the earth; moreover flowers spring up, and the earth's crust becomes covered with vegetation. 5. And many mountains have been converted into lime, and seem to have been burnt up by fire. All these circumstances appear to prove the existence of a central fire, which in particular places bursts through the crust that encloses it.

I admit that it is undeniable that a certain subterranean fire really exists; that is to say, that in some parts of the earth's crust a degree of heat is perceptible, which causes thermal springs, volcanic eruptions, and many other phenomena: but whether this heat proceeds from the earth's centre, and whether there be a cavity full of fire, or an igneous void—this is to the last degree questionable, and for the following reasons. 1. Because fire cannot live, unless it be enclosed in hard bodies, as in carbonaceous matter already mentioned as shut up with the fire in a furnace. 2. But if the furnace contain no solid fuel, although it be full of flames, no sooner is it closed, than the fire dies out, lasting in fact no longer than the heat remains in the hard bodies. Consequently fire cannot be kept in a cavity unless solid substances be present. If, therefore, there be any heat in the centre (supposing a central vacuum to exist), such heat must come from the substances of the crust, instead of the crustal heat proceeding from the centre. 3. Hence we may conclude that heat exists in many parts of the earth's crust, and not in others: but as for its source, and the manner in which it is kept up, see the preceding observations on Thermal Springs.

As to the second argument, that the equilibration of the earth in the ether cannot be conceived, unless we grant the existence of an intensely hot, light, fiery void, which like a hollow metallic globe by its mere lightness attains an equilibrium in the external element, I shall only briefly touch upon it, because men of the greatest scientific authority have demonstrated that the contrary is the fact. 1. I shall shew elsewhere, God willing, that the more fire a body contains, the heavier it is, and that the gravity of fire is increased by the quantity; or, what amounts to the same thing, that fire is far more ponderous

than ether, and consequently that the addition of fire is not the way to obtain levity. 2. We see the planets and our own earth move round the sun, as well as about their own axes, and in their own vortex, in which the satellites and moons are likewise balanced. 3. In the vortex we note a centripetal force, owing to which the heavier substances tend towards the centre, and the lighter towards the surface; and earth, water, air, ether succeed each other in regular order from the centre. 4. Let *ccc* (Fig. 44) represent the earth's crust, let *d* be the centre, which according to the opinion we are considering, is supposed to be empty, and very light, and let *aaa* be the surface of the vortex with the earth moving in it, beyond which there is a fluid ether. Now if we assign to the central cavity *d* the levity that ensures the equilibrium of so vast a crust, it will be more difficult to conceive how this equilibrium is produced, than if we place the levity in the vortex. Thus if the matter of the vortex *aaa* be lighter than the matter beyond it, the equilibrium will certainly be more intelligible. This may be proved by numerous experiments. 1. A stone or weight projected into the air, balances itself perfectly, as do all bodies in motion. 2. Also if these bodies are whirled round in the periphery of a wooden circle. 3. Water whirling round in a vessel does not fall to the centre, nor does mercury, though very heavy and mobile. 4. When mercury is placed in a glass vessel swinging from a string, its surface does not follow the slant of the oscillation. 5. If a weight be dropped down from the top of a ship's mast, and parallel thereto, it does not deviate an inch, or obey the course of the vessel. 6. If anything is thrown upwards in the ship, it falls down again in the same line, although in the meantime the ship may have advanced ten or twenty feet. 7. If any object be thrown from one ship into another, it passes in the same manner as if both vessels were stationary. 8. The same effect takes place in waggons and carriages: we see insects flying within them, as though they were in the most tranquil spot; and gnats likewise about the mane of the swiftest horse.

From all these facts it is evident, *firstly*, that solid bodies in motion will preserve their equilibrium in the air, or any other element, although there be no cavity within them to form

the equilibrium; so also the earth. *Secondly*. That a vortex is generated about all moving solids, in which the latter are at rest, and the vortex only is in motion. Thus the equilibrium of moving projectiles and solids appears to result from a circumambient vortex, which holds these ponderous bodies in its centre, and goes with them through the line of direction with a given velocity, but they fall down, or come to rest, when the vortex is destroyed.

The remaining arguments, drawn from the existence of volcanoes, boiling springs, &c., and many other natural phenomena, are more satisfactorily explained by the crustal heat of the earth, than by a subterranean fire in its centre.

The phenomena of Phosphorescence and of the Ignis Fatuus explained according to the Bullular Hypothesis.

It is a curious circumstance, that phosphorescence and the luminous matter of wild fire, or ignis fatuus, exist equally in cold and hot substances. Thus, 1. Certain kinds of stones, especially gems, as diamonds, &c., shine in the dark. 2. The hair of some animals, as horses, cats, and dogs, is luminous when rubbed. 3. When mercury in a vacuum is shaken, it yields a bright light, like a fiery shower. 4. Decayed and rotting wood emits a similar light in the dark. 5. And common salt, when broken in the water, causes the luminous appearance near oars, ships, &c. 6. Likewise when certain hard substances, as some kinds of salt, sugar, &c., are broken in the dark. 7. The shooting and falling star in the air, which so closely mimic the true stars of the firmament. 8. Marshes produce the most brilliant wild fires: I have seen some of these wandering flames as large as a lamp; which sometimes went out, and then were lit again, moving about from place to place, and two or three visible at once over snow and water; and more vivid and ruddy in the coldest air than at other times. I have often watched them with delight for a long time at a distance of a hundred and twenty feet. These fires are commonly called fire-dragons, and treasures are thought to be concealed under them. 9. So likewise the effluvia of metals shine like a candle

or white flame, as may be seen anywhere in Sweden. 10. The eyes of cats shine in the dark. 11. And glow-worms, especially in rainy weather. 12. Phosphorus, prepared from urinous substances. 13. Cylinders smeared with bituminous or sulphurous matters, and rubbed upon cloth. 14. And empty globes moved rapidly round their axis, the cavity of which appears to be on fire inside from the action of effluvia. In hot and dry substances these phenomena are still more evident. Thus, 1. Heat first and then light are excited by motion, as by the collision of flint and steel, by the friction of a hard and of a soft piece of wood together, of hard and soft stones, and a thousand other things. 2. A nitrous powder, which goes off in a flash when it comes in contact with the air, is formed of charcoal that has been shut up for a long time. 3. Besides other species of phosphorus, which catch fire in the air. 4. Not to mention that fire itself is kindled into flame, and the very atmosphere is lighted by the sun, in cold weather not less than in hot.

According to the bullular hypothesis, it follows that light is nothing more than undulation of the rays, or than vibration of the ether. It has already in some measure been shewn that the rays undulate when the ether vibrates. In this fact we have the explanation of phosphorescence and of the ignis fatuus, both in cold substances and hot, in dry as in moist, &c.

It would appear that the exquisitely minute particles of ether cannot exhibit the phenomena of light, unless they are struck by particles equally fine and small. If the latter be too large, nothing more than a slow and exceedingly dull undulation will take place in the former; but the reverse if both sets of particles be of one smallness. Thus, 1. The ether may be set vibrating by mercury with its very minute particles, especially in a vacuum. 2. In like manner the ether may be made to vibrate, or the ray to undulate, by any very subtle exhalations, either whole, or decomposed in the air, for instance, by saline *ramenta,* by urinous and sulphurous matters, provided their particles be extremely minute. 3. By the most delicate ramenta of salts, when broken, as in the sea. 4. By decayed wood, whilst emitting subtle particles. 5. And by the effluvia of certain animals excited by motion and friction. 6. I need

hardly say, also by fire, whose particles are so amazingly subtle, and when undulating will cause an undulation in the rays, or a vibration in the ether. 7. So also the rays from the sun will undulate through the whole sky. Hence according to the bullular hypothesis, it appears, for the reasons already stated, that light may arise in cold substances as well as in hot, and in the dry and the moist alike.

The sensation of sight points in a manner to a similar conclusion. The sensations that we have appear to be nothing more than the very subtle motions in the smaller particles: and as the most subtle motion amongst such particles can hardly be other than undulatory and vibratory, so I do not know why those persons should be mistaken, who maintain that sensations are merely vibrations or very subtle motions in the membranes of our frame. It does not seem possible that the light in our eyes can be, 1. Any quiescent or passive thing. 2. Or any occult quality, for we find in the organ a mechanism for receiving the rays. 3. We see the internal tunics or meninges brought from the interior of the head, and exposed immediately to the rays. 4. We see a variety of different tunics and fluids in the eye. 5. In the inner part, where the rays are collected, we observe a reticular lining, so that no ray can escape coming in contact with a considerable portion of the membrane therein. 6. We find these membranes conjoined with the internal membranes, and the rays received communicated to the meninges of the brain. 7. As therefore sensation must consist of some motion, and as the smallest motion is the vibratory and undulatory, I am not aware that there is any impropriety in assuming that sight or vision consists in the undulation of the rays in the membranes of the eye. 8. In the same manner as sound, which we know for certain is produced by the undulation of the air; for the ear is mechanically formed for its reception; it is tortuous, furnished with membranes, a tympanum, cochlea, various nerves of the utmost delicacy, malleus, incus, and all the apparatus necessary for vibration. These subjects, however, will be treated upon elsewhere. At present it is sufficient to have pointed out, that light is nothing more than a motion of the smallest particles, that is to say, of rays; and as the vibratory is the most subtle motion, we may perhaps find fresh proofs

of the existence of light in the bullular hypothesis and the principle of the undulation of rays. But as we are treating of invisibles, and as thought and geometry are alone at our service in the investigation, so we will submit our views to the criticism of the learned; and if they can bring forward facts to refute our notions, we shall receive the information in the most grateful spirit.

On the increments and degrees of Heat in Bodies, according to the Bullular Hypothesis.

The wonderful nature of heat and igneous particles is also plain from the fact, that heat increases more in solid and compact than in soft substances. Thus, 1. If wooden boards be exposed to a powerful summer sun, a much greater heat is perceptible in them than in the air. 2. If sheets of iron or copper be substituted for the wood, the heat is still greater. 3. I exposed flat pieces of copper, iron, stone, oak and pine timber to the action of the sun from daybreak until two o'clock in the afternoon, and the air was found to be pretty warm, though not by any means sensibly warm to the touch, like warm water; the pine timber was hotter, the oak hotter still, so that the hand could scarcely bear it; the stone was middling hot, but the copper was too hot to touch. 4. On repeating the experiment, I discovered that these substances varied in their degrees of heat according to their bulk and the thinness of the plates; that is to say, in the same time and from the same fire, a large body did not absorb the degree of heat proportioned to its compactness so quickly as the same body divided into plates; and therefore the experiment was most successful when the plates were of equal thickness. 5. The same fact may likewise be observed in charcoal, for the lighter kinds yield less fire than the heavier, pine charcoal less than beech, and beech less than fossil coal; so that the same amount of fusion may be performed with a smaller quantity of the heavier sorts. 6. And in domestic fires, the lighter woods afford less heat than the heavy; and in the walls of the stoves, the lighter stones supply less warmth than the heavy. 7. And in the large furnaces used in

iron, copper and silver works; which do not receive their full degree of heat in less than six, eight, or fourteen days, owing to the bulk and thickness of the wall: but as soon as they have obtained it, more ore and metal is melted near the wall than elsewhere. 8. In like manner mercury will receive a hotter fire than any other liquid. 9. The same rule holds in cold substances. Thus on exposing the same plates to the wintry sky, the air being very cold, snow is found to be still colder to the sense of touch; but iron is so intensely cold as to adhere to the skin, and almost to tear it away from the finger. I have not yet observed the effects of cold on the different kinds of wood, and on the metals. 10. Mercury is susceptible of most intense cold. 11. Water of the same temperature as the air is felt to be colder than the air; when cooled it freezes into ice, and is still colder than the air. 12. From these facts we may to a certain extent conclude, that the same heat and the same cold are much more increased in dense than in soft bodies, and that they are in proportion to the size of the pores; hence that in porous substances, as timber, scoriæ, bricks, &c., heat and cold are not circumstanced as in compact substances; or in old hard bodies as in recent, or in the elements and fluids as in the solids. These facts may be explained by the bullular hypothesis on the following mechanical rules. 1. We have already said that when the igneous matter is set in motion, it forms into bullæ; as also follows mechanically from so very intense a motion of the smaller particles, as in the case of water and other fluids. 2. It will be seen hereafter that the particles of fire enter through the finest pores, and make their escape through the larger. 3. Therefore, in proportion as the pore is small, the greater is the surface compared to the space, and the greater the quantity of particles that enter it. 4. If then these particles form into bullæ, the bullæ will be small in proportion as the particles are numerous. 5. The smaller the bullæ, the greater will their motion be. The smaller the bullæ, the less will be the volatilization, because the volume will be so much the heavier. And *vice versâ* in the larger pores, for they have less surface and more space, and consequently contain a smaller quantity of fire. 7. In proportion as there is little fire, the bullæ are large and dilated. 8. In proportion as the bullæ

are large, their velocity of motion is less, and their volatilization is rapid, because in the same proportion they are light. Hence there is a larger measure of heat in compact bodies, than in others of less density.

But the sources from which the matter of fire may come, have been pointed out in the preceding pages. 1. From the resolution or decomposition of air. 2. Its particles are inclosed in oily, nitrous, sulphurous substances, and in general in the small channels and pores of things. 3. They are set free by any moving volume of the same igneous matter. 4. And they enter through the minutest pores, pass into the minutest cavities, and form bullæ, and then exhale through the larger orifices. Each of these points will be considered in our Theory of Fire. But as most of the experiments are still wanting, and as we are treating of minimal and invisible things, so we can only advance our views at present hypothetically and doubtfully.

PART IV.

OF THE

MISCELLANEOUS OBSERVATIONS

CONNECTED WITH

THE PHYSICAL SCIENCES,

AND ESPECIALLY

ON THE MINERALS, IRON, AND THE STALACTITES IN BAUMANN'S CAVERN.

THE ORIGINAL PUBLISHED AT SCHIFFBECK, NEAR HAMBURGH, IN 1722.

To His Most Serene Highness, Ludwig Rudolph, *Duke of Brunswick and Luneburg.*

Most Serene Prince,—

The following pages are too unimportant to constitute a worthy offering to your Highness; at whose feet the great works of the masters of learning alone are deserving to be laid. But as small things frequently afford pleasure to illustrious men, and as your Highness is aware that victims of slender value were presented at the altars of the gods, and that a little frankincense was offered in propitiation to their divinities, so I also, encouraged by such great precedents, am not without hope that these few pages which I have ventured to dedicate to your most Serene Highness, and to place upon your altar, may meet with a gracious reception; were it for no other reason, than that in part I present you with your own, with a record derived from the Baumann's Cavern, to which my access was your own most gracious permission. And still the greatest reliance that I have in supplicating your favour, is in the knowledge that you are as illustrious in spirit as in descent,

as distinguished in mind as in renown; and that the world accords to your personal virtues the same free honour as to the extended sway and imperial diadem of the Cæsars.

But if the offering that I bring is small, my veneration at least is greater than the offering; nay, so great, that I desire nothing more ardently than to be permitted to be,

Most Serene Prince,

Your most humble and devoted servant,

EMANUEL SWEDENBORG.

MISCELLANEOUS OBSERVATIONS.

PART IV.

On a new Sexagenary Calculus, invented by Charles XII., of glorious memory, late King of Sweden.

As the adventures, actions, and lives of illustrious men in the learned world belong to the history of literature, and constitute its glory, especially when they are at once illustrious in mind and by heroic deeds, (for such are worthy of double laurels, of one wreath for their genius, and the other for their fortune and birth,) so I consider that what I am about to relate of the sexagenary calculus invented by King Charles XII., of glorious memory, will be found highly worthy to be recorded and remembered. I suppose that not one man in a thousand would imagine that a hero of such renown, gathered from so many achievements, possessed also a most profound and acute judgment, and a force of mind the most penetrating in all matters belonging to arithmetical calculation. But it was my good fortune frequently to hear him discourse on such subjects, in particular, as belong to mathematics and arithmetic, and I will now give an account of a mode of calculation invented by him, which will afford a sufficient example of his power.

One day the conversation happened to turn on the nature and origin of arithmetical calculation, and the method in general use was shewn to be only an artificial, and not a natural plan; that is to say, that the simple numbers run in one series up to the tenth character, then in a double series to twenty,

and so on through the third, fourth, and other numbers, to a hundred, and to 1,000, 100,000, &c. It was remarked that this method had arisen from some ancient custom of counting with the fingers; for when the rustic and simple people of early times had reckoned up to the last finger, they began again in a new series, and again arrived at the same point, by following their ten fingers, and so on until they had thus gone over them ten times; which would be denoted by conjoining two marks or fingers, then three, four, and so forth. Afterwards, when this method of calculation was distinguished by numbers, it would of course keep its original character, after having been so long received in practice, and taught on the fingers. The difficulty of devising any more expeditious calculus was also an additional reason for the general adoption of this method; hence at the present day, we make use of that system whose limits and periods lie in the decimal number. But had a geometrician, or a person well skilled in the fundamental principles of arithmetic, been appointed to furnish the world with a method of calculation, of greater utility and convenience, he would never have selected the decimal system, but rather have based his plan upon some other number, which by dividing or halving would constantly return to the beginning of the calculus, or to unity, and which would have contained the square or cube of some number; or which would have been more in conformity with our measures and weights, and with the divisions of money. Many other particulars were mentioned, with which his Majesty was so greatly pleased, that he immediately desired to make a trial with a calculus of a different nature or order; but as this could not possibly be accomplished unless additional numbers or characters, with fresh denominations, were provided, he at once began with the octonary scale, which, as he observed, would not only return by halving to unity, or the commencement of the calculus, without any fraction, but would likewise contain the cube of the number 2, and when doubled or quadrupled, would agree with certain weights and series of coins up to 16 and 32, received in general use. He therefore commanded me to attempt an example of this new calculus, which I accordingly prepared in the course of a few days, with the addition of those points of agreement which the

octonary scale would possess with the coins, weights, and measures in use at present, together with an easier method for finding the cubes, squares, and other calculations more speedily: in short, I mentioned everything which appeared to illustrate the new attempt.

When his Majesty had looked at my specimen twice or thrice, although he saw that it clearly had certain advantages unknown in the decimal calculus, yet he would not honour it with his approbation, because, as far as we could judge, he considered it too easy both in conception and practice. He therefore immediately said, that he wished some other number than eight to have been selected; some number, in short, which might contain both a cube and a square, and yet be referred to the octonary scale, and reducible to unity by constantly halving. As the number including all these conditions could only be 64, which contains the cube of 4, and the square of 8, and by halving is reduced to the commencement of its series, or unity, without leaving any fraction, I ventured at once to object that such a series of numbers would be far too long; and that to proceed uninterruptedly by simple numbers to 64, then in a double series to 4,096, and then in a triple series to 262,144, before the fourth term would begin, would occasion an incredible difficulty in calculating, not only in subtracting and adding, but especially in dividing and multiplying. For it would be necessary to commit to memory 3,969 numbers for the multiplication table, whilst the octonary scale would require only 49, and even the decimal no more than 81, which is yet a wearisome effort for some persons to remember and apply. But in proportion as I raised difficulties, his Majesty only became more eager and desirous to try this calculus, *Per ardua visus est velle niti;* he seemed to court difficulties, and would give no other reply, than that those I had alleged would be compensated by greater advantages.

A day or two afterwards, I was once more summoned before his late Majesty, who resumed the subject of this new calculus, and enquired whether I had attempted it? As I was again bringing forward the difficulties already mentioned, his Majesty took from his table a paper, containing new characters and fresh denominations for numbers, in his own hand-writing,

which at my request was handed to me; and to my great astonishment, I saw he had invented not only new characters and numbers (bearing a considerable resemblance to the letters of his own name), and which proceeded in a regular series to 64, by a most happy and easily-remembered division, but likewise fresh denominations; both being so contrived that they might be extended to myriads, whilst the character and denomination would constantly vary. But when I perceived collaterally some new methods for performing addition and multiplication by this calculus, which were produced artificially, or by characteristic marks in the numbers themselves, together with other most ingenious attempts to facilitate the employment of this system, I could not but admire the heroic force of his mind; and, full of wonder, I felt obliged to confess that this great monarch and man was not merely my rival, but my conqueror in my own department.

And as I am still in possession of the manuscript in the royal hand-writing, and as we ought to commit to the safe keeping of the press all those subjects which are most deserving, so I shall, at a future opportunity, lay these characters before the public, together with the methods of calculating with them. They will certainly shew what an active faculty for device his Majesty enjoyed, and how profoundly he had penetrated into the deepest secrets of arithmetical science.

Another proof of his skill in calculation was afforded by the ease with which he could solve the most difficult problems by mental operations simply, which would have required from others the most laborious and fatiguing methods. And here we may just notice, that when he was at Bender, he composed an entire volume on military exercises, which is highly esteemed by the most able members of that profession. Hence also, when thinking of the benefits derived from mathematical and arithmetical science, he used to say, That he who could not calculate was scarcely half a man.

Reasons to shew that Mineral Effluvia or Particles penetrate into their Matrices, and impregnate them with Metal, by means of water as a vehicle.

There are many opinions respecting the impregnation of matrices and the generation of metals in the bowels of the earth; and as the causes and origins of these results are remote from our sight, they must be investigated by hypotheses or ideas, assisted by the numerous examples which present themselves in every direction to the notice of the enquirer. We have to consider, then, what it is that conveys the effluvia, and what it is that insinuates the metals and sulphurs into stones.

It has been ingeniously supposed by many persons, that there is a peculiar fire, solar or central, that penetrates into the most hidden recesses, and enters the minutest pores, together with the subtler exhalations, and thus enriches stones with metals, by filling them with certain heavy and foreign particles. That this effect is produced by the solar fire, may perhaps be doubted, for the following reasons. 1. Because the veins very frequently appear to be richer in the deepest and most hidden parts than near the surface; and it is hardly consonant with reason to imagine that the solar rays can reach these places, and penetrate to such a depth towards the centre of the earth, especially as there are obstacles, not only in water, but likewise in the very diverse parts of the soil and in compact rocks impervious to the solar rays, and of the coldest temperament; all of which would at least deaden and impede the heat issuing from the sun, or prevent it from proceeding to any great depth. 2. The rocks are as rich in metal in the coldest parts towards the north, as in countries near the equator; in Lapland and in the north of Sweden, the veins are often richer than in the south. But if these veins derive their origin, or form an influx, from the sun and its rays, the latter being supposed to contain a subtle sulphur, and to pass from the fiery oceans of the world through the atmosphere into the lowest region of the earth, then we must first ascertain whether a very oblique sun, as in Lapland, can produce the same amount of effect as a more perpendicular radiation? And here I need hardly remark,

that three-fourths of the heat (if the influx be deduced from the heat, and not from the rays) will be entirely stopped in its course by the cold that reigns during the year, and binds up the mountains. 3. We may also add, that wherever any metallic vein is found, especially if it be rich, experience testifies that the climate is sensibly colder, and a wintry sphere exhales from the very mountains. Thus, if we take the Saxon, Luneburg, or other mines, how intense is the cold in those localities! the case is the same with the Swedish and Lapland mines, although the surrounding district may have a comparatively warm and vernal atmosphere. Hence, also, mineral mountains are generally covered with snow, whilst others in their vicinity are gently moistened with the dews of spring; the air is felt to be cold on the mineral mountain, when it is temperate on a neighbouring elevation of equal height. To pass over the innumerable instances which Sweden affords, I remarked that at a little distance from the mines of Eisleben, the atmosphere was of a temperate and agreeable warmth, but that it was very cold where the works were carried on, although they were not a quarter of a Swedish mile distant, and scarcely any higher. A similar difference was observed during the winter season in many other places. Thus it appears that the mineral mountains are not impregnated by either the solar or central fire or heat, since they partake less of heat than of cold, and emit effluvia rather than admit them. If therefore cold and heat could in any way agree, we might then perhaps conceive that by the action of the heat derived either from the sun or from the centre of the earth, particles might be carried into the veins, which may in themselves be cold, and which seem to be perceptibly so in various places.

I am not at present speaking of the origin of the effluvia or exhalations, but only of their ingress into the veins: should any one be inclined to deduce the origin of the particles from any kind of fire, above or below, I shall not here oppose him. Nor shall I object to any one concluding that there is an influx of metallic particles from the rays of the planets, or from the lightest and most mobile rays of the sun, which may still be extremely cold.

In support of our opinion, that metallic exhalations and

particles penetrate into the rocks and impregnate their matrices through the medium of water, several probable reasons are derived from the following circumstances; which will, I think, prove experimentally, that the same effect may be accomplished by the action of water, as by the subtlest particles of the sun or of any central fire.

1. We find that some waters are strongly impregnated with the effluvia of various metals, and that they generally run from the clefts of those mountains that are rich in veins of the same metals. Many of these springs exist in Sweden, Germany, and especially in the country about Liège, at Spa, in Hungary, England, and elsewhere; consequently it is undeniable that the effluvia and subtler particles of the metals frequently lurk in the aqueous particles. So great is the profusion of springs impregnated with vitriolic matters, with iron, copper, silver, and many other mixtures and species of metals and salts, that to enumerate them would be a long and useless task. Thus we see that the very subtle particles of any of the metals may be easily hidden amongst those of water, flow with them, and in their company pass through any substances they meet; in short, that the one order of particles holds a natural place among the other. 2. And experience demonstrates that this is not peculiar to metallic particles alone, for it also obtains with every description of vitriolic, aluminous, nitrous, and other saline particles, which not only will accompany a volume of aqueous particles, but will live and travel in it naturally. 3. It is still more extraordinary, that even sulphur and oil, which otherwise will hardly mix with watery fluids under any circumstances, are found mingled with these waters; and that, so intimately, *i.e.*, in such minute elementary particles, that when the water stirs, they emit their peculiar odour, much as under the action of fire; as abundant experience shews to be the case with medicated and vitriolated waters. It appears, therefore, that the subtlest particles of sulphur, those nearest to its infancy and origin as a substance, accompany the aqueous particles, and penetrate into the same places with them. But when the same sulphur has coalesced and formed larger particles, it is hardly miscible with the aqueous particles; for this combination only takes place whilst it is very minute, and has not yet assumed

its peculiar fixed nature. 4. This view may be confirmed by additional experiments; as by the solution of metals by the appropriate menstrua. Thus, by the assistance of certain acids, gold itself, silver, copper, and the other metals may be dissolved and rendered fluid in water. Mercury, without any other menstruum than simple hot water, may be divided, and assume somewhat of the same fluid property as the water. The whole of these experiments prove that the subtlest particles of the metals will remain in water, as their own natural fluid, and will make use of it as a vehicle to penetrate in every direction: likewise that the metallic particles or effluvia may exist in the waters, and pass with them through the clefts and crevices of the rocks, and thus, as we have said, by the medium of water, run into the matrices of metals.

It now, on the other hand, is necessary to shew, that water itself has the power to pass through the subtlest pores of stone, and to run in every direction, upwards and downwards, through the clefts of rocks. That such is the fact, is evident from the following reasons. It is well known, 1. That water will enter the smallest pores, into which air and still subtler matter cannot penetrate; thus waters will insinuate themselves readily into the pores of stone, in sufficient abundance sensibly to increase the weight of the mass. I have frequently seen this experiment tried with stones which had been immersed for a considerable time in the beds of rivers, and with fragments of rock blasted by gunpowder from the roofs and sides of mines, and the water has often exuded from them in considerable quantity; consequently its particles must be subtle enough to run freely into stones, especially into those which have wide pores. 2. Nor does it penetrate into stones alone, but also into certain metals, as into the pores of copper and iron; and experiment shews that warm water may be driven even through gold. That water passes through the clefts and strata of mountains, both upwards and downwards, is sufficiently proved by the following experiment. Take two flat surfaces, and apply them accurately to each other, so as to allow no passage for air; on immersing one end in water, the fluid immediately rises as though spontaneously, and comes out at the upper end, and this with rapidity when the passage has been once moistened. The same effect

takes place in ashes, in all spongy substances, between the closest fissures of the strata, and in other fine apertures. Whence it may appear, that water will penetrate the subtlest pores of rocks, and especially those stones which are divided into layers or cubes, &c.; that it rises along the strata, both upwards and laterally or obliquely, in a vacuum as well as in the atmosphere; in short, that it has the power of running into the more porous kinds of stones, as in matrices, which will be again remarked in the following pages.

But this possibility will not yet allow us to form true and dogmatical conclusions, or boldly to assert that metals are carried into their matrices by the sole instrumentality of water; unless, indeed, we can maintain ourselves by experience, and confirm our position by reasons grounded in the first instance on probability. Of such reasons the following are examples. 1. Aqueous exudations exist in most mines, in considerable quantity in some cases, more sparingly in others: and we observe that liquids drip from the veriest hard rocks, covering and moistening the sides and roofs of the mines, although not a crevice is visible in any part. 2. In some mines the water is accompanied by a vitriolic, or genuine metallic, or sulphureous salt; as at Fhalun in Sweden, and at Gosslar, where the walls are frequently encrusted with saline deposits, which sometimes depend in drops like icicles; so that it is plain that a peculiar juice permeates the pores of the rocks, and carries with it the metal or salt, which thus gradually insinuates itself into its matrix. 3. In mines consisting of strata, we may constantly see the water flowing, or see that it once flowed at the borders of the strata of rock, and that wherever a passage was afforded, it has insinuated itself into the interior of the stratum. And this water seems so highly impregnated with metallic particles, that its colour, weight, and taste enable the miners to form an opinion on the condition and quality of the ore in the strata. 4. The surfaces between these strata and the rocks are generally covered with a species of clay, the strata being actually softened into clay, and at the same time distinctly coloured. All these indications shew, that the water had constantly trickled between the strata; and being impregnated with metals, had everywhere penetrated into those matrices or stones, whose pores are the

best suited for its reception. 5. Moreover, this water often gushes forth from the surface, and forms a fountain or spring, which is impregnated with similar substances, as vitriol, sulphur, alum, iron, copper, silver, lead, &c. 6. When we examine the matrices, of which whole strata are often formed, such as spar, quartz, dropping stone, &c., they are found to consist of continuous layers, either of cubes or triangles, in the interstices of which the water passes in every direction. Thus it seems to enter at the edge of the stratum by the planes of apposition, and in course of time to fill them with the metallic particles that it has brought with it. Hence those stones seem to be the best adapted for matrices, which consist of the above cubes and layers, whose interstices afford a passage for the water which it does not find elsewhere. 7. Hence also we remark that the spar, &c., varies greatly in colour; being white, red, or shining, according as it is dyed by different coloured waters: the weight likewise varies, some spars being lighter than others, and they are often found to differ in these respects, according as they are near the vein, or more remote from it. Besides, we perceive most clearly in ores that effluvia insinuate themselves through the thin layers of the stones, or the interstices of the cubes in quartz, spar, &c.; so that the very layers themselves appear to be divided and denoted by the ore, which afterwards by the medium of the same water creeps transversely and obliquely into all the planes of the layers, until it occupies the entire mass. 8. Hence, also, we have ores as brilliant as spar, which are frequently rich in metal, as iron, lead, tin, silver, &c., and many others, which prove that the water enters along the minutest flat surfaces of the layers into the matrices, and carries the metallic particles with it. 9. This is still more visible in scissile stones full of ore, as in those of Eisleben and other places; in which mines the ore is only found on the surfaces of the layers, which shine with sulphureous, golden, coppery, and other glowing tints. Nor do the exhalations seem to have penetrated into the actual substance of the stone, but only between its layers, or into those parts which were open to the permeating streams, and through which the fluids rise upwards, according to repeated experiments; in this manner fresh metallic intermediate strata appear to be formed. So also in mineral stones

partly consisting of another kind of rock, we find that the surfaces are usually occupied by sulphur, vitriol, or metal, which gradually extend from thence into their interior; that is to say, these substances originate in those places, through which the water, it seems, can run and carry the metallic particles with it. 10. Nor should we omit to mention, that the richest veins are covered with stagnant water; yet not constantly; although experience certainly shows that where the rocks are comparatively rich in veins, adjacent parts, both above and below, are moister than elsewhere; whence the wildfire or ignis fatuus is generally seen in marshy places. 11. Do we not often find the more porous stones full of real native silver and copper? Do we not often see pieces of wood impregnated with these metals? I myself have seen the trunks of oaks, beset with true copper all along the filaments of the wood where water formerly ran; and I have noticed fir timber injected with silver in the same manner, with many other substances, affording a passage for water only, which had deposited in those places the particles that it held in solution. This is still more clear in those places where specimens are found preserving the shape of fish, the whole form shining with copper; which is a sufficiently evident sign that the water had permeated the fissures and interstices, and in its passage had covered not only the surfaces with very delicate plates and incrustations, but had likewise deposited the same materials in the interior of the fishes, &c. 12. And if we consider the native crystallization of metals, we recognize the same traces and forms that we daily see produced by the agency of water. Thus, sometimes they appear as filaments, issuing in straight and oblique lines from their crevices or matrices, through which water of some kind seems to have oozed, and generated long icicles and capillary formations. And do we not also find that the metal grows from the same stone as the crystals? which, it is pretty well agreed, derive their origin from the vapour of some watery fluid. Moreover, we often see crystals covered with the ore of some metal, which occupies either their interstices or their external surface, or endeavours to disengage itself from their inner substance. All these circumstances seem to point out, that both the crystals and the rudiments of these ores are formed by the agency of

some fluid. And do not some vitriolated waters contain so much copper, that the latter exceeds the iron in amount? This cause is the more likely to explain the generation of metals, as there may be a subtle sulphur lurking in the waters, together with vitriol and many other substances, which give rise to marcasites first, and then to metals. For if sulphurated water passes through porous stones, it would not be extraordinary for the more irregular particles to remain in the pores, and for those which are comparatively regular to pass onwards; in other words, the sulphur, vitriol, and metallic particles may occupy the minute spaces, when the water that was their vehicle escapes. 13. If we examine a single metal, and its mode of growth, as silver for example, we find that its ore is of different kinds; sometimes the red species of silver ore exists in crystals, as though these crystals had been produced in the same way as stony crystals, by the action of a fluid dropping from a rock. We see native silver in thin plates, or in capillary filaments, or in branches and very elegant arborescent figures, having a root in the matrix, from which they spring upward in luxuriant ramifications. All these circumstances point to the existence of a peculiar fluid that generated the figures we have mentioned, and arranged the particles in definite forms and positions. This appears to happen in the same way that silver, when dissolved in a menstruum with mercury and water, or some precipitating salt, gives rise to the *Arbor Lunæ*, or tree of Diana, or to hexagonal crystals, or thin plates. Since these are plainly produced by the instrumentality of water, we may conclude that the others also are due to the same agency. 14. The same variety is very evident in the other metals likewise; thus a vein of lead, and of tin likewise, often forms crystals of different colours: and I have seen the ores of iron, and again of other metals, possessing the same forms as the crystals, both therefore having the same origin; and as the crystals are produced by a fluid exuding from the rocks, so it may be supposed that the richer crystals of these metals originated in the same manner. 15. In certain dendritic gems we observe formations like trees and groves, which are frequently tinged with some mineral fluid; the branches are sometimes sulphurated, sometimes silvered, &c., which apparently could only be caused by the agency of

water. 16. In the same way, when the ores grow again in the veins after a lapse of years, it has been ascertained that the reproduction takes place in moist localities, or where the land is submerged; but as fire is contrary to water, so, in our opinion, the reproduction must rather be ascribed to the latter than the former. 17. We are enabled to strengthen this conclusion from certain lakes and rivers, in the beds of which the sand contains gold, silver, or iron; which again may be owing to the agency of water. Thus, *firstly*, at the bottom of some lakes, &c., both in Sweden and other parts, we find iron in almost a native state, which is annually taken away and rendered ductile: the bottom, thus frequently cleared of its ferruginous sand, nevertheless, after some time, is again enriched with the same, and in the same abundance as before. It is difficult to account for this, unless we suppose the ferruginous particles to exist in the waters, from which they fall to the bottom as a sediment, and yield a fresh crop every year. Certainly we cannot ascribe it to torrents or winds, since there are none such in these places to agitate the waters, or carry the sands thither. *Secondly*, we have some waters, and indeed whole lakes and rivers, full of sand containing copper, tin, and silver. How can we account for this, unless particles lurk in the water, which on meeting with a fitting matrix amongst the sands, take possession of it, and impregnate it with metal? A similar course of reasoning is applicable to the gold that is often found in river sand. 18. Experience also testifies, that mineral exhalations sometimes creep up through the roots and stems of certain trees and shrubs: thus, in some estates in Hungary, &c., grapes and vines are said to have been found that were impregnated with gold; the particles of which, in company with water, may have found their way into the inner channels of the growing vines, &c.

If, then, the native metals, which are every now and then found in the mines, be compared with the precipitates of the same metal, thrown down from menstrua, we shall observe the greatest similarity between the two classes of productions; and we shall see reason to conclude, that water serves as a vehicle to carry metallic effluvia and particles into their matrices. But should it be objected, that very dry veins are often found with-

out a drop of moisture about the ore, and consequently that the presence of the ore cannot be due to the agency of water, we may reply that water creeps through the subtler pores imperceptibly, altogether differently from the way in which it permeates the larger passages. When the pores are small, the water rises up through them gradually, in such minute volumes, that it cannot be observed; in proof of which we may cite various species of stones, as marbles, stalactites, &c., which contain water in their substance. And we all know that water creeps up insensibly through ashes, through the filaments and ducts of plants, the layers of scissile stones, sponges, sugars, salts, tubes of very small bore, &c.; though where the passages are large, the water falls down them, and runs, in fact, in the opposite direction. Thus we may say that water runs downwards through the open and wide crevices or interstices in strata and rocks, and then creeps into the finer pores, or between the finer layers of the matrices.

But *secondly*, it may be objected, that in the mines we frequently meet with water of the purest quality, containing no traces either of sulphur, vitriol, or metal. Certainly this is not a very common occurrence, yet that it may happen we do not deny; but we suggest that whatever metallic matter it contained, may have been stopped on its passage, and the purer fluid only have escaped. We are now, however, treating only of the entrance of metallic particles into their matrices, not of the origin and generation of the particles themselves; this, therefore, is not the proper place for considering whether such particles are the produce of rays, or of a solar or central fire, or of some other cause.

Since, therefore, the above-mentioned waters are of such very different kinds, some being impregnated with sulphurs, others with mercury, and others again with salt or other particles adapted to this combination, and if we may form an opinion accordingly, we conjecture that such or such a metal grows or is composed by the meeting of these different waters. And perhaps posterity will discover some art, unknown to us, of making certain species of metals by the mixture of different waters impregnated with sulphurs, vitriols, &c. On the above principle it is, that in the same matrix and in the same stratum

we frequently find four or five kinds of metals together, thus silver is frequently mixed with copper, lead, and gold; copper with zinc, bismuth, tin, cobalt, and marcasites of the most various kinds; which, in our opinion, may have derived their origin from the meeting of different waters, that brought with them the most simple particles of sulphur, salts, mercuries, &c., &c.

On Stalactites, and Crystallizations of Stone; with remarks upon the resemblance of these formations to Congealed Water.

We possess the clearest evidence that the dropping stone, or stalactite, is produced by the water dripping through the fissures and pores of stones; in proof of which, we need only quote the admirable phenomena of the Caverns of Baumann,* although many other caves of the same nature exist elsewhere. The roof and sides are full of stalactites resembling icicles and cylinders, the different forms being determined by the different obliquity of parts of the rock, and of the streamlets, as chance had caused the moisture from the slender crevices to flow into one or more places. In these observations, however, we intend merely to treat of the resemblance of these forms to water while freezing into ice.

There are two kinds of stones which appear to have derived their origin from this petrifying water; 1. Dropping stones, or stalactites, and 2. Stony Crystals. Both these kinds present nearly the same appearance and character as congealed water.

We find that the resemblance of the first kind, or stalactite, to water, is manifestly shewn, 1. In the external shape; the icicles hanging from any part of the roofs of houses, seem to be formed in the same manner. Thus they are extended in length; they are in part cylindrical; in part, owing to a slight obliquity, they are conical, lamellated, and uneven, or interspersed with tubules and swellings. This pendulous ice assumes the shape of tongues and other organs, with many different and curious forms that we admire in stalactites. The evident cause

* So called, because a person named Baumann was lost in them.—*(Tr.)*

of these appearances lies in the origin of both substances from the dropping of water, for each of them receives its increase from the liquid proceeding towards the end, whilst its bulk is augmented by the variety of water flowing beneath. 2. On comparing the external form of these two substances more closely, we remark that the stone produced by the dripping water has channels and lines of various kinds, and planes intersecting each other at certain angles, and especially curving like a fringe; the same appearances may be observed in ice, for when either fluid falls obliquely, it cannot fail to become hardened here and there, and to generate a form agreeable to its motion, which is usually sinuous and serpentine. 3. If we inspect the internal arrangement and composition of the particles of stalactites, we observe that it is the same as in ice, though not in every kind; there is the same fracture, according to the same angles; the same brilliancy and sparkling appearance: this identity being necessarily produced by the aqueous origin of both substances. Thus we may suppose that in the stalactite, the position of the particles is the same as in congealed water; and in the latter nearly the same as in fluid water: there is a subtle matter, which in warm weather appears to lie in the interstices, and by its mobility prevents the particles from joining together; but when, by the loss of heat, it has either escaped or collected into globules, the same particles are bound into ice by their mutual contact; but the stalactites coalesce into a stony hardness by the agency of larger particles occupying the spaces of the aqueous. We think, therefore, that the difference consists in this circumstance, that in ice the spaces we have just mentioned are empty, but in the stalactite, they are filled by largish particles that fit the shape of the little volumes; whence it follows, (although not yet as a certainty,) that the arrangement, texture, and order of the particles are nearly the same in the ice as in the stalactite. But as we are treating of invisibles, we can only arrive at this conclusion by reasons drawn from analogy; if, however, this can afford assistance in unravelling the mysteries of nature, the conclusion must be considered as established in so far, until experience teach the contrary.

As to the second kind of stone that is produced by a petrifying fluid or moisture, which gradually dropping produces stony

crystals and other growths, forms, or vegetations; this kind, I say, has its exact analogue in ice; it differs however from the stalactite. 1. In exuding by degrees from rocks only and the hard substance of stones, as from the stalactite itself, from spar, quartz, &c.; and in growing out in various forms, as hexagons, triangles, pentagons, pyramids, and frequently into transverse lines. 2. It is generally produced in the smaller subterranean caves and hollows, especially were certain metallic effluvia are found; though here and there on the tops of mountains. 3. The particles of this second kind of stone appear evidently to have a different arrangement, which gives rise to pentagonal, hexagonal, and other angular forms, as may be seen in a variety of crystallizations. 4. Hence this second kind is distinguished from the first by fracturing triangularly, and in pyramidal, prismatic, and parallelogrammic forms; whilst the former fractures cubically and in square planes. The first kind is commonly termed quartz; the second, spar.

This latter sort of stone presents several points of resemblance to ice. Thus, 1. On ice, or on water once converted into ice, we find a number of shapes rising like vegetations, many of them fashioned by means of a certain moisture exuding from the hard ice. So we see similar kinds of germination about the stones described in the preceding pages; shewing that a fluid exudes or oozes in a similar way from both the hard ice and the rock, and imitates those vegetable forms that spring up from the soft ground. 2. On rocks, and in little crevices, fissures and caverns, we see hexagonal crystals springing up, nearly resembling those of nitre, vitriol, alum, precipitated metals, &c: the same appearance may be seen on ice, especially when the cold is very intense; of this germination we have spoken in Part III. of these *Miscellaneous Observations*, p. 82. At Gosslar also I noticed a peculiar crystal exactly of the figure delineated in the above account, viz., consisting of hexagonal plates upon a crystalline stalk. Moreover other forms may be seen on ice, which exhibit a parallelism with those belonging to crystals, as triangular, pyramidal, prismatic forms, &c. 3. Upon stones we frequently observe raised lines with tranverse ridges intersecting each other, such lines being produced by means of some fluid trickling from their interior; ice also,

during intense cold, presents the same appearance, and the lines meet each other and cross in layers, and thus form the same shapes as exist in figured stones. 4. We see growths, like icicles, filaments and foliage, springing from the rocks; and parallel formations may be observed on ice; with many other productions referable to nature's play.

We have thus described two kinds of stone, which are considered to be formed by water or fluid; viz., the stalactite, and the crystalline. The former derives its origin from the water trickling through the crevices of mountains, which hardens in nearly the same manner as ordinary water congeals into ice: this sort of stone fractures for the most part cubically. But the second kind, the matter of which exudes and distils from the very pores and the hard mass of the same rock, in the same way as hexagonal and other figures are formed from the hard ice, generally breaks triangularly. Both kinds, therefore, arising as they do from an aqueous juice, although by a different process, exhibit a most striking analogy with the hardening of water into ice, which is all that I have at present attempted to shew.

On the Petrifying Fluid or Juice; with remarks to prove that it is not identical with the water that produces the stalactite.

The following particulars respecting the dropping water that converts substances into stone, are especially observable in Baumann's Caverns. 1. This water descends through the fissures and pores of the rock above it, which is of that kind usually designated horn-stone. 2. It is very limpid, like water from a fountain, or water containing a small quantity of common salt, which is generally more pellucid than water that is perfectly sweet. 3. It is perfectly sweet to the taste, but particularly cold. 4. To the touch, it is just like ordinary water, but being much impregnated with stony particles, it makes the skin dry and rough, as if it had been bathed with a solution of vitriol or alum. 5. As it drops from the roof or sides, and produces forms like icicles, the insides of the drops are at first

void and empty, but afterwards are filled with water particles, and in the course of time grow hard. All these facts indicate, that the water, in penetrating the rock, becomes impregnated with stony particles, though not in such abundance as to occupy all its interstices, or to convert the whole volume into stone, but only to change that part which constitutes the crust of the drop; leaving in the interior a cavity until fresh stony particles are added, by means of which all the water in this cavity is in process of time converted into stone.

But to proceed to our subject, which is, to prove that the water that gives origin to the stalactite, is not the same as the water or juice which petrifies vegetables inclosed in stone or sand, as wood and leaves, and animals, such as fishes, quadrupeds, bones, &c. This is confirmed by what is observed in those places where stalactites are formed, especially in the celebrated caverns of Baumann, and in those of Schartzfeld, which contain a surprising quantity of bones of different animals, vertebræ, leg bones, teeth, &c., &c. Now though these bones have lain in this situation for a great number of years, the true character of bone still exists in all that remains of them, nor do they seem to be petrified in any part. Thus, 1. I observed some bones almost decayed, full of pores and perfectly spongy; nevertheless they still maintained their osseous character, nor did a single orifice or channel exhibit petrifaction, although I gathered several specimens, of many of which from these localities I am now in possession. 2. These caverns also contained some bones which still preserved their osseous nature, although they were inclosed in stalactites, and surrounded by stony matter on every side; as my specimens will demonstrate. 3. We may likewise observe a sort of earth in these caverns, which will not petrify, although surrounded with stalactite. From which we may conclude that the water that generates the stalactite is not the fluid which causes the stony hardness in soft bodies.

Besides, it is well known that in many places there are waters which have the natural property, not of petrifying, but only of incrusting substances. Branches of trees, foliage, leaves, herbs, and mosses may frequently be seen incrusted with stone, so that at the first glance they might be mistaken for petrifac-

tions; although they really preserve their own natural softness within, and are merely covered with stone, like the bones mentioned above as inclosed in stalactite.

If, then, we may use conjectures and ideas, in conjunction with experience, to enable us to prosecute those subjects that are not obvious to the external senses, we may suppose that the petrifying juice is the fluid which oozes and exudes from the harder stones, such as spar, quartz, stalactite, &c.; or is the same fluid that converts soft substances into rock or stone, and otherwise forms into crystals. Our reason is, that this fluid is much more subtle than the dropping water already mentioned as producing the stalactite, and the stony particles contained in it are smaller and subtler than those existing in the latter; in the same way as when salt water is subjected to distillation, the larger saline particles are broken into smaller ones, that is, into acids, which in this state appear to exert quite a different effect from that of the salts when larger and entire.*

In the preceding pages we have in some measure pointed out, that one description of stone is produced by the dropping water, and another kind by the fluid oozing from the pores of the stones; by means of the latter, crystals and figures as of plants are formed. The first kind of stone generally assumes cubic shapes, but the second prefers the pyramidal and triangular; like salts, which, if entire, crystallize cubically in water, but if broken, they crystallize triangularly. Hence we may with some confidence assert, that the subtler fluid of the latter kind is the agent which converts soft bodies into stone, or has the petrifying property; and this view is confirmed by the circumstance, that the petrification of soft substances generally takes place in closed places, where the surrounding stone is comparatively hard, as well as in those very localities where crystals are produced. I am in possession of some of these petrifactions, and I have seen shells covered on every side with crystal, their valves consisting only of a crystalline and pellucid substance.

* On this subject see the author's Theories of Salt and Acid in his *Chemical Specimens*, p. 55, 67.—*(Tr.)*

On the formation of Quartz and Spar; with reasons shewing the probability of their post-diluvian origin.

No kinds of stone require a more careful examination than spar and quartz; for the ores of all kinds of metals are generally enclosed in them. We find that they are commonly impregnated with gold, silver, copper, tin, lead, sulphur, &c.; while the neigbouring strata, being of another kind, are free from these substances, and incapable of receiving ores or minerals. As, therefore, these two sorts of stone are generally the matrices of ores, and as some of their varieties are used as fluxes in smelting furnaces, we consider it of the utmost importance to investigate their nature. In this place, however, we shall only treat of their origin, which we are not inclined to attribute at all to clay, soil, or any other matter existing before or during the Deluge, but solely to water and petrifying juices at subsequent periods. There are many probable arguments in support of this view, by which, if they seem to be of weight, we shall afterwards be enabled to arrive at some more certain conclusion respecting the texture and character of the particles of these kinds of stone. Thus, 1. We find that the fissures and crevices of mountains are usually filled with these kinds of stone; wherever the rock is seen to have opened, or to have been cracked in former times, it may be observed that spar or quartz have agglutinated the fractured parts; indicating that in process of time, some petrifying water or juice has occupied these vacant spaces, and filled them with these peculiar stones. 2. A similar result may be remarked in small strata; very slender veins, or thin intermediate layers, are frequently seen between the layers of scissile stones; these veins consist of spar and quartz, and appear to have bound the other layers together into rock, frequently of very great hardness; in consequence of this infiltration, we can hardly meet with any strata or layers of this kind of scissile stone, as at present it only lies in a sort of contiguous arrangement. 3. In the mines we not only find whole strata filled with this description of stone, but irregular spaces also, which sometimes are shaped like cones, sometimes like round cavities; occasionally they represent clefts or caverns

of various dimensions, as would be distinctly perceptible, if they were empty. These places are called kernels and nests, because they are generally found to contain ore, which however does not continue beyond the farther extremity of the cavern or mass. Nor indeed does any view seem more consonant to reason, than the opinion that these spaces were at first empty, but in process of time have been filled up by means of some fluid or juice exuding from the rock. Experience also is in our favour. Thus we meet with caverns of this kind, like Baumann's and many others, still empty under the mountains, and frequently extending for several miles, and very irregularly shaped throughout. In time, these caverns are filled with stalactites, which gradually block them up; and thus at the present day we have the very process going on before our eyes, which we find accomplished in the mines. 4. It appears that the same conclusion may be drawn from the resemblance of the stalactite to spar, and of the crystallized stones to quartz; we observe the same texture in the stalactite as in the spar, the only difference being that the latter breaks into wider planes and larger cubes than the former. If we enquire the cause of this difference, we see clearly enough that the stalactite might be divided into planes of the same magnitude, if the fluid divisor had but penetrated between the planes, and made the same stone capable of division into larger cubes. The same remark applies to quartz. 5. This may be confirmed by what we know of spar supporting the most intense fire; a quality possessed by stalactites also; by the fracture in both substances taking places in cubes; by their likewise agreeing in colour, unless the spar be impregnated by a mineral water. Thus stalactite seems to be converted into spar by some mineral or saline water having permeated its layers, and run between its planes. Hence, also, I have remarked in many mines, that the stalactite stone occupied an entire stratum or cavern, and a vein enriched with some kind of mineral passed through the middle of it; next to which was spar, of a different colour and weight, but there was nothing near the spar or around it but stalactite: this subject, however, will be better entertained hereafter. 6. Our theory is also supported by the fact, that crystals still grow in a thousand small orifices, and gradually take possession of the vacant space by

continually uniting, and thus produce a peculiar quartz, which has a triangular fracture. As we observe these changes taking place at the present day, the points of agreement afford us grounds for thinking, although not for positively asserting, that all these kinds of stone have been formed since the time of the Deluge.

Still more to strengthen this opinion, we might quote the evidence afforded by a thousand other places and mines; we shall however only mention the copper mine in Lauterberg, called *Kupperros*, which is an excellent example. Should any one wish to explore this mine, and examine its ore thoroughly in the stratum, he will plainly see the agreement with our hypothesis of all those facts which we have adduced in its support. He will there see, 1. A stratum of considerable size, descending from the surface of the mountain to its lower parts, and exhibiting various swellings and enlargements on the way: thus in some places it dilates to twenty or thirty ells in width, whilst in others it is contracted to three or four, and then again swells out. 2. At a depth of about one hundred and eighty ells, this stratum consists altogether of sand, in which, however, a vein of copper is concealed, but the colours vary in different ways; so that this metallic vein appears to have slipped down into the sand together with the upper part of the stratum. 3. Nearer the bottom, this stratum becomes harder, and stony; and the hardness increases with the depth; but it still occasionally expands and contracts as before, always continuing to sink lower. 4. On examining the sort of stone of which this stratum consists, it is found to be neither spar nor quartz, but an intermediate species evidently stalactitic, being very white, of the same grain as stalactite, of the same weight, and possessing the same properties under the action of fire: the workmen themselves assert the same fact. 5. In some places stalactites are formed which closely resemble in their structure or constitution the stone of the stratum wherein they are. 6. The richest copper vein passes through a stratum of this stone, and cuts it in two; the next layer to the copper vein is spar, a white stone fracturing into large cubes, and more compact and heavy than stalactite, &c.

Here we find our opinion vastly strengthened. 1. It is a true stalactite that occupies the entire stratum to a thickness

and depth of so many ells: at this very day it is reproduced, and its nature is not denied by any of the workmen in the place who know anything about the matter. 2. When we consider the extent and varying form of this stratum, we recognize most distinctly the empty caverns which in process of time have been filled up by stalactite: there are the same bulgings and enlargements, exactly as in the Baumann, Schartzfeld, and other caverns, through which the vein of copper ore has made a passage for itself. 3. What is the spar here but the offspring of the stalactite? with the addition of hardness and increased gravity. 4. How is it that this stratum with the ore on its upper part has been softened into sand, whilst the lower portion still remains hard and rocky? How, but because the same stone has crumbled into sand under the action of some kind of watery fluid? The same kind of stone is recognized in sand; the same kind of ore is converted into sand; and moreover, we see a part softened into sand by the simple accession of water: which process of softening I have already noticed in another place in these *Miscellaneous Observations*, p. 44, 48. I need not mention the numerous instances afforded by other mines, since the example we have selected surpasses all the rest; I can only refer the incredulous to Baumann's Caverns, and to the copper mine in Lauterberg; to the former as shewing very similar spaces, which are being filled in the lapse of ages; to the latter as containing the same spaces, but filled up already.

But should any of my readers be desirous of pursuing the subject, and of enquiring into the cause of these and similar strata and caverns that in time are filled with stones by the medium of a watery fluid, this, we beg to inform him, is not the place for such an exercise. Nevertheless, as numerous causes may be given, I will mention a few of them. It is very clear that the first matter of mountains was soft and argillaceous; we might expect, therefore, that when it hardened into stone, 1. A mountain would have crevices in various parts, forming intervals and vacant spaces. 2. Nor does it seem possible to deny, that when an argillaceous mountain was violently brought together into one mass, water might be enclosed in many places, and hollows or caverns be formed accordingly. 3. In some parts, torrents of water arising from small begin-

nings, might penetrate through the softer rocks of the kind, and gradually excavate considerable hollows. 4. Mountains may likewise have subsided and been swallowed up; perhaps also they may have vomited fire. Such we imagine to be the origin of the caverns and strata afterwards filled by this stony matter. But as we are not professing to speak on this subject, we merely allude to it briefly, leaving the rest to be supplied by the learned reader.

General observations on Furnaces for smelting Iron, with suggestions for improving them.

As nothing is of greater antiquity or utility, both in its experimental and theoretical aspects, than the art of smelting metals, so I believe there is nothing of which it is more difficult to acquire a knowledge. The practical experience is generally confined to the unlettered and rude portion of the smelters, who preserve and daily use the rules handed down to them by their masters, parents, or others, but do not attempt to examine them more profoundly, or to propose to themselves the accurate knowledge and amelioration of their fires, metals and furnaces, because they are unacquainted with the true principles, and because each man considers his own knowledge the best. As to the theory or more intimate consideration of these matters, there are several highly competent and sagacious enquirers who have entered upon it; but being destitute of the practical information, they do not appear to have the required foundations on which their ingenious minds and acute reflections should rest.

This is the reason of the great discrepancy which exists at present between the different modes of treating metals; of the employment of so many different furnaces for the same ore; of so many varieties in the hearths and fires in which the metal is reduced; and of the numerous ways in which the fire itself is applied. Now, although the investigation of all these subjects is an undertaking beyond my powers, it may nevertheless be right and proper to bring forward those points touching the furnaces used in smelting iron, which are dictated by experience,

and those which are dictated by first principles; in order that others may afterwards supply what is deficient by a just combination of talent with opportunity and experience, and that at length we may elicit principles on which the improvement of iron furnaces may be based.

To arrive at the true method of treating a given ore, the following circumstances must be carefully considered. 1. The nature of the ore, its composition, what proportions of stone, sulphur, and metal it contains, the effects produced upon it by fire, &c. 2. The proper construction of the furnaces as to form, height, capacity, and other necessary points required for the ore. 3. We must not omit the fire-hearth or focus in which the ore is liquefied, and which is as it were the spring and life of smelting operations. 4. The blast likewise must be proportioned to the ore and furnaces. 5. And it is of the highest importance that the quality and proportion of the fire be considered with respect to the furnaces, fuel, ores, &c. Unless due regard be paid to these five points, and unless both experience and theory confirm the result, I believe that all our labour will be in vain, and any success ascribable to fortune alone.

In this place we intend to treat only of iron, and iron furnaces: but we shall first give general rules and observations as to the fire, the furnace, and the manner of reduction.

Iron ore is of different kinds; thus it may be, 1. Pure and genuine. 2. Poor in metal. 3. Rich in metal. 4. Mixed with stone, which may melt either easily, or not, at the same heat as the ore. 5. Or it may be impregnated with sulphur. 6. Or with different kinds of metals. All these circumstances must be duly considered, if we wish to obtain the true shape in the furnace, and the proper effect in the fire.

As to the furnaces, I shall instance a Swedish specimen, in order that our rules may be stated by examples, and not as theory alone. This furnace agrees in every respect with the figures and description in my *New Observations and Discoveries respecting Iron and Fire, and particularly respecting the elemental nature of Fire: together with a new construction of Stoves*:* it is very lofty, bellies out in the middle, is narrower

* *Some Specimens of a Work on the Principles of Chemistry, with other Treatises*, p. 181. 1847.

below than above, and in short, exactly answers to the dimensions given in that work.

The most general rules. When the ore falls amongst the charcoal in the cavity of this furnace. 1. In the upper part, it is calcined and freed from the superfluous and dense sulphur, or from its more volatile part, if any be present. 2. The ore is liquefied and melted in the middle, where the furnace widens to form the belly, and consequently the heat is most intense. 3. In the lower part, through which the ore runs in drops, it is separated from its scoriæ and stony accompaniments. 4. In the focus, the separation is more thoroughly effected by means of the motion and blast, whereby the lighter parts remain on the surface, while the heavier sink to the bottom. Such are the more general rules; although we might cite a hundred other special directions, some of which will be seen in the following pages.

I. If the belly be too spacious and ample, or exceeds the given proportion, then, 1. The ore will be dissolved too suddenly and violently, and be broken up rather than melted. For if the belly surpass its proper dimensions, the fire will be too intense, because it increases with the space; hence a disruption of the particles will take place rather than a complete resolution. This violent action gives rise to the following results: 2. A part of the ore will be vitrified, or converted into scoriæ with the stony part. 3. Its sulphureous parts, if still present, will intimately mingle with and adulterate the iron. 4. Thus the quantity of iron will be diminished, and the remainder will not be of the desired good quality, because a wrong disposition of its particles will ensue. I need hardly mention that the belly will, nevertheless, dilate spontaneously by the continued fusion.

II. If the furnace has no belly in its middle part, but expands towards the bottom to form a cone, as in several of the German furnaces, then the following results take place. 1. The ore certainly is properly calcined, and freed from the more volatile and sulphureous matter; provided, that is to say, the furnace be lofty, and the cone not very oblique. 2. But it cannot be so effectually separated from its stony part; for unless the melted ore falls down dividedly and by drops into the fire, and

has sufficient space to run in the furnace when the liquefaction is completed, the foreign substances remain; and in the focus, when present in large volumes, they cannot possibly be removed. 3. Hence the iron is deteriorated, and is not of good quality. 4. Moreover, owing to this enlargement, the blast is too soon dispersed, and is driven upwards, with a loss of fuel, from the focus where it ought to produce its effect: unless these evils be guarded against by narrowing the aperture, as I have sometimes seen done.

III. If the belly be above the middle half, then, 1. The ore will not be so completely calcined, and purified from the sulphur and volatile substances. 2. It will liquefy too soon and carry the sulphur with it into the focus, where it is impossible afterwards to separate it. Hence the kind of iron produced will contain sulphur, and be brittle when hot, and tenacious when cold. 3. This form of furnace also allows the larger fire existing in the upper part to consume a great quantity of charcoal.

IV. If the upper part of the furnace be too broad and open, then, 1. The ore is suddenly exposed to too violent a heat, and melted before its sulphureous part has escaped. 2. And the charcoal is burnt away without producing the proper effect on the ore, whereby a double loss is sustained.

V. If the sides of the furnace be square instead of round, then, 1. The effect of the fire on the ore and charcoal varies; there is a different degree of heat in the angles and adjacent parts, to that at the sides nearer the centre. 2. More fire penetrates into one part of the wall than into another. 3. The inequality of the fusion occasions an irregularity in the quality of the metal. 4. And more charcoal is consumed in the square furnaces than in the round, owing to this inequality of the heat diffused through the ore and the fuel.

VI. If the furnace be too low, 1. The effect of calcination is immediately lost. 2. And if the sulphur is not driven off, the stony matters are not properly separated. 3. There is also too little heat in the focus. 4. And the blast escapes too quickly, and consumes a disproportionate quantity of fuel.

VII. If the furnace be very lofty, 1. There is more heat in the focus. 2. The blast produces a better effect. 3. The

charcoal is expended more rapidly, but a greater weight of ore may be thrown in, or, which comes to the same thing, the usual charge may be introduced more frequently. 4. It appears, therefore, that a smaller quantity of fuel is burnt with a better effect. 5. At the same time the superfluous sulphur is properly expelled, and thus the stone is prepared for the separation of the scoriæ and for fusion.

VIII. If the furnace be wider than the due proportion, both in the upper and lower parts, that is, if it be more capacious, then, 1. The degree of fire is too great to allow the first heating and calcination of the ore to be duly performed. 2. The ore is dissolved and melted too rapidly in the upper part, and too violently in the lower; whereby the iron is contaminated both with the sulphur and the stony matter. 3. The consumption of charcoal is also greater than necessary. 4. And a smaller quantity of iron is procured, because a part of it is converted into glass and dross.

IX. If the furnace be parallel from the top to the bottom, 1. The fusion is not completed in the proper time. 2. The ore is first melted in the focus, in consequence of which its impurities cannot be separated. 3. Besides, to be completely and intimately dissolved, iron requires a most intense heat, which it ought to receive in the proper place, if we wish to avoid waste of fuel and loss of metal.

X. If the lower part of the furnace or focus, called in Sweden the *stelle*, be too ample, 1. The blast cannot penetrate to the opposite side, or circulate as it ought; nor can it set the fluid mass in motion, and separate the scoriæ from the metal. 2. But before the blast has reached the centre, it is dispersed upwards, the surface of the charcoal is blown off, and the fuel is spoiled, without the due effect being produced on the ore; for the blast ought to proceed round the sides, and ascend from them, but not to rise up in the middle. 3. Besides, there is too great a heat above the focus, which violently loosens the particles, and produces the prejudicial effect mentioned in the preceding pages. For the particles may be very easily broken by too much heat in the focus, when the ore flows down dividedly in drops; hence skilful smelters observe most carefully,

through the orifice for the bellows, the colour and pellucidity of the drops as they are running downwards.

XI. If the focus or *stelle* be longer than it should be, but at the same time narrower, as it frequently is in the German furnaces, the following results are occasioned. 1. The iron which is melted does not afterwards receive a sufficiently powerful fire, owing to the extensive sides in this shape, which greatly moderate and diminish the intensity of the fire. 2. The fluid mass cannot be agitated by the blast, for the perfect separation of the scoriæ, owing both to the figure of the focus, and also to the greater coolness of the metal. 3. If above this focus, the furnace be of ample dimensions, as in several of the German smelting works, the melted ore retains its stony components most tenaciously, and the iron is of a bad quality. 4. The ore cannot be rendered fluid unless by adding a large quantity of menstruum or flux, *i.e.*, of a lime stone, called *kurim* in many localities; but this measure is attended by an increased expenditure of charcoal, and loss of iron. 5. But the chief objection is, that a smaller charge of ore must be introduced, amounting to scarcely a half or a third of the quantity which might be melted if the focus were of a different form and proportion. 6. Besides, the plate of the orifice for the bellows cannot be placed obliquely, for on the least inclination the mass immediately cools; and consequently, owing to its horizontal direction, the blast is carried into the middle of the furnace, and the fuel is burnt away to no purpose.

XII. If this focus be too narrow, it gives rise to the same inconveniences; a great quantity of the flux or *kurim* is required for the fusion of the ore and the separation of the impurities: consequently there is a useless consumption of charcoal without any improvement in the iron; and the hourly charge of ore cannot be introduced in the proper proportion.

XIII. If the stones or sides of the fire-hearth be too thick, certain disadvantages ensue. Thus, 1, the iron cools and adheres to the sides, so that a large quantity of flux must be melted with it. 2. A comparatively small charge of ore must be introduced, especially when there is a double row of these stones, as in the German furnaces.

XIV. If the bottom of the focus be damp, or the stones have not been thoroughly dried, or the passage beneath is improperly constructed, &c., the same disadvantages are to be apprehended; the fuel is unprofitably and uselessly spent, a large quantity of calcareous stone must be added, whereby the quality of the iron is deteriorated; not to mention that less than half the usual charge of ore must be introduced.

XV. If the blast be not duly proportioned to the dimensions of the furnace and fire-hearth, the smelting is injured. For, 1. The mass of liquefied iron is not moved as it should be. 2. The scoriæ are not separated from the metal. 3. Nor is there a sufficient supply of air to the combustible matter; there is, therefore, a want of fire in the charcoal, and consequently, of effect on the ore, which must be compensated by an increased quantity of fuel.

XVI. If the passage or orifice for the blast be too horizontal, 1. The mass of iron is not set in motion by the air. 2. The blast is immediately carried away to the upper parts, but is not diffused towards every side, so as to exert an equal action on the charcoal; the latter, therefore, is consumed, without the ore being properly melted. 3. When, however, the focus or *stelle* is longer and narrower, this orifice ought to be horizontal; if oblique, the mass of iron might cool; which must be guarded against by the combustion of an undue proportion of charcoal.

XVII. If the position of the orifice for the blast be too oblique, the melted ore cools round the opening of the bellows; the cold air passing to the middle of the mass, which it cools and frequently hollows out, as experience demonstrates. This is often seen under the opening, a cold hollow being formed in the middle of the metal.

XVIII. If the due proportion of fuel and ore be not observed, thus if too much charcoal be introduced, then, 1. The iron may be vitrified, and partially converted into scoriæ: and the mass will appear glassy, silvery, and sparkling; also very brittle, and lighter than otherwise; in short, of the worst quality. 2. To say nothing of the useless consumption of charcoal. Thus the proper quantities must be ascertained by particular signs.

XIX. But if there be more ore than charcoal, 1. The iron will indeed be duly calcined, yet not smelted. 2. The stony part

will remain, and some of the ore will pass in a crude state into the focus. 3. Hence the metallic mass will be glittering and brittle. 4. It is also to be feared that the volume of iron will harden on account of the low heat, and the melting be brought to a stand. Nevertheless, it is sometimes necessary to obtain iron of a harder quality, less roasted, &c., as for certain cast articles, anvils, &c., which are usually manufactured with a smaller quantity of fuel.

XX. If the different ores be not justly porportioned, especially when many kinds are used, several inconveniences will arise. For it is important to adapt the furnace to the ore; and this, both in height and width, in the shape of the focus, in the proportioning and distribution of the blast, and of the orifice. But when many sorts of ore are to be melted, they may all be treated in the same furnace by mixing them together and calcining them in various proportions.

In order, therefore, to accomplish the smelting of iron satisfactorily, and to obtain metal of the best quality, with the smallest expenditure of fuel, the following points are necessary to be observed. 1. The furnace should be of the proper shape, as well as the focus or fire-hearth; and the orifice of the blast should be fitly placed. 2. The smelter should be skilful, as otherwise he may succeed but indifferently, even with the best of furnaces. 3. The proper mixtures of the various kinds of ores should be well ascertained. 4. Afterwards, in the furnace where the iron is re-melted and rendered malleable, all the processes should be skilfully performed. By observing these essentials, we cannot fail to obtain a superior description of iron, with a comparatively small consumption of charcoal.

Since, therefore, it is in the nature of iron to bear the hottest fire, yet when melted to be easily vitrified, and at the same time converted into scoriæ, also to mix with stone, as well as with sulphur and certain metals; and since it is consumed by sulphur, and flies away with it in fumes, therefore we must not only know all these points, but also apply them; 1. In the true construction of the furnace. 2. In calculating the proportions of the lower fire-hearth and blast. 3. The calcination of the different kinds of ore. 4. The proportions for mixing the same. 5. The right times and places for introducing charges of the

proper weight. 6. The relative quantities of the fuel and ore; and many other circumstances, which none but skilful smelters can know. And although each kind of iron ore requires a peculiar treatment, and appropriate furnaces, fire-hearths, and blasts, yet art can effect much in enabling any or all of them together to be properly reduced in one and the same furnace.

Such are the general rules and observations respecting iron and the furnaces in which it is smelted. Guided by them, I will now describe a new kind of furnace, which I think will be best adapted for fusing the different kinds of iron ores. 1. It should be round, like the furnaces generally used in Sweden, and of the same dimensions, both above and below; thus the diameter of the mouth may be three ells; of the belly, four ells; and of the lower portion, two ells and a third, which are nearly the measurements of the common Swedish furnaces. 2. But it should be two or three ells higher than them. 3. The sides of the upper portion should be almost parallel. 4. In proportion as this furnace is more lofty than that in ordinary use, the belly may be placed lower down, so as to be in the middle of the furnace, supposing it to be of the common height and construction. 5. The focus beneath should be built of bricks made of French clay, as it is called, which has the property of resisting the action of the fire; this clay is found in many parts of Germany, as well as in France. 6. The shape of the focus must be oval, somewhat broader above than below. 7. Underneath it there should be an arch built of the same kind of bricks, as they cannot be injured by the violence of the fire. 8. A passage is to be made from one side of the furnace to the other, for the heat to escape. 9. Under these, there is a plate of iron, beneath which again there is a passage for the evaporation of water. 10. If the sides of the furnace be protected with the above-mentioned bricks, the fierceness of the heat will be prevented from damaging the walls. 11. The bellows should be heavy, and they ought to be placed as nearly as possible to the smaller diameter of the oval or ellipse formed by the focus.

The following advantages result from these arrangements. 1. The ore is thoroughly calcined from its sulphureous parts before it arrives at the blast. 2. The fusion or melting takes

place near the belly, exactly in the same way as in the common Swedish furnaces, but with greater profit, as the ore is purified from sulphur. 3. And it is freed also from its stony part below. 4. The elliptic fire-hearths afford a more intense heat than those in ordinary use; they have a less extensive cooling surface; they contain more space within the same lateral dimensions, especially when they are broad above, and shaped like a truncated cone. 5. The blast likewise appears to be more completely diffused around the surface of the iron, and at length to rush upwards at the sides of the furnace. 9. The foundation of the fire-hearth, or the arch underneath it, built of the same kind of bricks, makes the mass of liquid iron in the focus still more intensely hot. 7. The weight of the bellows also assists in producing this result.

Thus, as the grand difficulty lies in such a construction of the focus, that the ore shall run into it in a proper manner, and be supplied with a degree of heat sufficient for its fusion, so when our construction is perfect, the following results ensue. 1. A larger quantity of ore may be introduced in the same time; solely owing to the shape and heat of the fire-hearth, as is well known to the Swedish smelters. 2. There is no necessity for so much flux or calcareous stone, (*kurim*, as it is called,) as is indispensably requisite in the narrower and cooler furnaces. 3. The blast can be augmented to any degree that may be necessary, as the argillaceous stone or brick resists the energy of the hottest fire: not to mention other points, which must be previously confirmed by experience.*

* In the *Observations respecting Iron and Fire* (p. 183), the smelting furnace was said to be capable of holding about two hundred tons of charcoal: the Swedish ton there mentioned is the *Skeppund*, which is equal to about four hundred English pounds.—*(Tr.)*

END OF THE MISC. OBS.

APPENDIX.

PAPERS BY SWEDENBORG

FROM THE

ACTA LITERARIA SVECIÆ.

APPENDIX.

PAPERS BY SWEDENBORG FROM THE ACTA LITERARIA SVECIÆ.*

Letter to Jacob a Melle.

Most learned Sir,—

I HAVE lately received the description, which you had the goodness to send me, of the figured stones found in the environs of Lubeck: and I am rejoiced to find that the researches of the learned are everywhere bringing to light at the present day so many indubitable evidences of the existence of the primeval ocean. Many parts of Sweden abound in figured stones, and in various kinds of petrifactions, of which the Provincial Physician, Dr. John Hessel, formed an excellent collection in West Gothland. Our most distinguished collectors of these objects are, Dr. Magnus Bromell, Assessor of the Royal College of the Mines, who some time ago had many figured stones and other petrifactions engraved on copper; and Dr. Lawrence Roberg, Professor of Medicine in the University of Upsala. To their labours and to yours we are indebted for some remarkable attestations of the depth of the primeval ocean.

That the land on which we now dwell was formerly the bed of a sea, is clearly shewn by these and many other circumstances. On a high hill, not far from the city of Uddevalla, there is an entire tract of land consisting of different kinds of

* Two of these papers were translated into English in the *Acta Germanica*, vol. i.; London, 1742: this letter, at pp. 66—68, and the following one, on Heat, at pp. 122—124.—*(Tr.)*

shells and of tortoises: a similar formation exists near Strömstadt, in a still more lofty hill, seventy ells above the level of the sea, and also in the islands of Tiorn and Oroust. These remains are so abundant, that the inhabitants burn them, and thus obtain a most excellent lime, which they sell throughout the district. It would be well worth while to engrave the several species of these tortoises, as they are exceedingly numerous.

Strata of the most various kinds may be observed in Sweden; as, for example, in the mines throughout the country, and especially in one in the province of Schonen, not far from the city of Landscrona: they may also be studied in the shattered remains of several hills, and in the slopes of the highest mountains, as Kinnekulla, Billingen, &c.

That the ocean formerly stood at a considerable elevation above our soil, is more conclusively shewn by the appearance of the earth towards the north, than by that of the countries farther to the south. In our own country, whole provinces are filled with stones of immense size and weight, scattered over their surface; and these masses are larger and more numerous, as the district is at a greater height above the level of the sea. In a treatise, written in Swedish,* which you have deigned to quote in your remarks, I have endeavoured to shew that at the bottom of a deep and rolling sea, stones of vast weight may have been carried about and transported over the globe; that this was the fact, may be deduced from the following hydrostatic grounds. 1. Stone, compared to its bulk of water, does not weigh more than $2\frac{1}{2}$ to 1; and to salt water, still less. 2. Consequently, in the water nearly half its weight is lost; and instead of $2\frac{1}{2}$, only $1\frac{1}{2}$ remains. 3. Hence the weight of the stone is not so perceptible in the sea as in the air, for the aqueous element is so heavy, that it is nearly equal to the remaining weight of the stone; that is to say, if the stone, whilst in water, weighs to water as $1\frac{1}{2}$ to 1, it will, whilst in air, weigh to air as 2,000 to 1, at least. 4. Therefore, if the waves

* *Om Wattnens Hoegd, och foerra Werldens starka Ebb och Flod, Bewis utur Swerige.* 8vo. Stockholm, 1719. Arguments derived from appearances in Sweden in favour of the depth of the waters, and greater tides of the sea in the ancient world.—(*Tr.*)

act on the sea at its bottom, as storms drive the atmosphere at its bottom, where we dwell, and if the column of the sea be several hundred fathoms deep, the impulsive force of the water fluctuating at the bottom will certainly be increased in the ratio of its depth and base; consequently, a sea wave continued towards the bottom has more power, owing to its depth, than the same wave on the surface. 5. The primeval ocean, therefore, must have been able to tear away rocks of enormous bulk from the hills, to carry them along in its course, and to strew them over the soil in various directions; also to disturb the whole of its own bed. 6. These changes it effected in the same way as the atmosphere acts at its bottom on sand, wood, bark, leaves, feathers, rags, and many other such substances: for when the air is set in motion by a tempest, these bodies are caught up and carried aloft, as though they were really lighter than itself. This appears to be partly owing to the height of the atmosphere, which, when set in motion by the weight of its own column, imparts a power to the storm, like that of a large body in motion. 7. Many examples of this principle are afforded by embankments, or water dykes, formed by a double planking, filled with heaps of stones: thus, whenever the water rises three or four ells, which generally happens in the spring, it has sufficient power to overthrow the dyke, and carry away the stones sometimes to a distance of above a hundred yards. This is owing to the height of the water. Hence, in places in Sweden at a great elevation from the sea, as in the district of Orebro, which is between the two seas, the fragments of rock are larger and more numerous than elsewhere; for they could be conveyed thither by the following waves, but not higher, because they would be nearer the surface.

From these facts we may infer that the inequalities in the surface of our present soil were caused by this ocean; and that all the uneven formations of mud, shells, sand, and stones, were produced by the waters fluctuating at its bottom. Hence would arise, 1. So many hills of different kinds and shapes. 2. So many strata in them. 3. Many mountainous ridges, stretching for eight or ten miles, and consisting partly of sand, partly of pebbles, and partly of large rocks. 4. A roundness in the very pebbles of which these vast ridges are composed;

for they are as if polished in a lathe, a sign that they have been driven about and rubbed against each other by a constant rolling motion at the bottom of the sea. 5. These views are greatly strengthened by the fact, that the backs of these ridges of hills in Sweden generally run from north to south; this appears to have been occasioned by the constant easterly and westerly winds, like those which prevail at this day in the great ocean: for such winds must necessarily have existed in the diluvian northern ocean, as there was no shore, &c.

These circumstances might have taken place in a deluge; but it may perhaps be doubted whether they all happened during the Deluge of Noah, which lasted only one year. For in many places which are, at present, forty or fifty ells above the level of our sea, the timbers and ribs of large vessels are yet found; and in the very mountains there are hooks, rings, mooring places, and many other signs proving that the ancient inhabitants possessed a port in that spot; and it is certain that towards the north the level of the Baltic is still gradually subsiding at the rate of four or five ells in depth within seventy years. Hence many places are now under the plough, which once were navigable for shipping; and crops are raised where fish were formerly taken. I have myself seen these marine places, and have heard old people speaking of them. In Western Bothnia, within a single century, there are towns that have been in this way removed from the shore, and their ports are now several hundred, or even a thousand yards distant from their ancient localities: of which, the city of Upsala and several others may be quoted as examples. These facts tend to shew, that all such changes did not take place in the universal Deluge; but that for a long time afterwards, the lands, towards the north in particular, were buried under a deep ocean, whence they gradually emerged as the sea subsided towards the north; or, in other words, its bed became habitable. If this view should derive additional confirmation from other discoveries, similar to your researches in the vicinity of Lubeck, we shall have grounds for believing, though not yet for asserting, that, 1. The horizontal pressure of our world is liable to change; which necessarily follows, if the seas are depressed towards the poles, and raised, as reported, towards

the equator. 2. Consequently the distances of latitude vary. 3. Certain lands, at present continents, may formerly have been islands, which have united in course of time as the sea subsided. There are many other points, which I do not venture to publish until I am furnished with additional proofs, and thus enabled to proceed on a firmer foundation.

In the meantime, it is pleasant to investigate the causes of things, and to listen to those who have the genius to penetrate into the secrets of nature, and the industry and strength to evolve the ancient from the modern world. Amongst these enquirers, most learned Sir, I include yourself, and most sincerely do I trust that you may long live to confer benefits upon science.

Stockholm, May 21, 1721.*

New Rules for maintaining Heat in Rooms.†

In the northern countries the method of preserving the warmth of rooms is entirely different from that in use in countries nearer the south. In the former, close stoves are employed, whereby the heat retained in the burnt wood and charcoal enters the apartment, and fills it with warmth, which lasts for the whole day. In the latter, a different plan is adopted. But I will now mention the rules by which the heat may be maintained in rooms where the stove is closed by plates, &c.

I. Rooms constructed of timber are warmer than those built of stone; that is to say, wooden walls supply a greater heat than those of stone. This is owing to stones incessantly emitting a certain degree of cold, which diminishes the heat near the walls. Consequently, a room will feel cold in proportion as it has a large surface of stone wall, but warm when it has a surface of timber. To confirm this fact by experiments, place a large stone in the fire-place, and you will find that the fire

* Extracted from the *Acta Literaria Sveciæ*, vol. i., anno 1721, pp. 192—196.

† From an original letter, in the *Acta Literaria Sveciæ*, vol. i., anno 1721, pp. 282—285.—*(Tr.)*

immediately loses much of its power, because cold exhales from the stone. A sensation of cold is always experienced near any large stone. Walk on a stone pavement, and in a short time you will feel in the soles of your feet a sensation of cold, which will soon affect the whole of your body. Sit upon a stone, and in less than a quarter of an hour you will feel great cold. Place a block of ice in a room, either in a corner, or under the table, and you will feel a great degree of cold exhaling from it, and indeed to a considerable distance; this exhalation is according to the size of the ice.

In like manner, the more wood enters into the construction of the room, the warmer it is. Thus, if the walls, tables, chairs, and other furniture be made of wood, they radiate neither cold nor heat; but when their heat is in the least increased, they immediately diffuse a very gentle warmth, which lasts for a long time.

If the stone walls are lined with wainscot or hung with tapestry, a greater degree of warmth can be maintained in the same apartment than if the walls are bare; for the lining prevents the cold from striking so far from the stone, and diluting the heat in its neighbourhood. Hence, by these means, the heat may be greatly preserved.

Also, if the stone walls are covered with a thick coat of plaster, for the plaster does not exhale so much cold as the bare stone; hence it not only absorbs the cold, but prevents it from entering the room.

Walls built with the common grey stone emit more cold than others: and this, in proportion to the size of the stones, or the thickness of the walls; as is very perceptible in churches. Brick walls emit less cold.

When the stone is porous and light, it emits less cold, and receives heat with greater facility; such is the case with the scoriæ of iron and lime. In like manner, wood preserves heat in proportion as it is porous and impregnated with sulphur.

II. Thin walls of stone contain and preserve the heat in a room better than thick ones. This assertion seems contrary to principles in the opinion of many, who think that the thicker the stone wall, the better is it adapted for keeping the external cold from penetrating through its crevices. But they do not

consider that an intense cold exhales from the stones themselves, and this in proportion to their thickness; for it is scarcely possible to heat such walls, even in a considerable period. Experience also shews us that in those places where there has been no fire, the cold which exhales from the walls is felt for a long time. As an additional confirmation of our view, we may mention that a pane of glass, although so exceedingly thin, is of the nature of stone; nevertheless, owing to its thinness, no cold exhales from it. In like manner, there is much less cold in a thin piece of ice than in a thick block. Hence, if the walls were built only a single brick in thickness, the room would be warmer than if they were constructed of the most enormous stones.

III. The greater the surface of the timber walls in proportion to the space, the warmer is the room; which is a necessary consequence of the preceding facts. Hence, a square room is warmer than a round one; an oblong, warmer than a square; and the more oblong it is, the warmer does it become.

The greater the space on the floor and walls which the fire in the stove can occupy with its rays, or heat, the warmer will the apartment be. Consequently, low rooms are warmer than lofty ones, because there is both much surface to little space, and the heat does not rise so high; for it is about the ceiling that the warmth accumulates. The contrary holds good in buildings with bare stone walls.

IV. The heat will be well preserved in an apartment in proportion as the upper parts of the roof and ceiling are well closed, compact, and free from crevices. The heat flows out like a stream; but it will not escape, if the cracks are in the lower parts of the room, its tendency being to ascend, not descend. Hence, no heat passes out through the lower openings, but the external wind and cold enter thereby, and by their pressure drive the heat through the upper parts. Hence the rule, that the fewer chinks there are in the upper part of a house, or the more compact it is, the better.

The farther a crevice is from the ceiling, the less prejudicial it is, and the less heat escapes through it, but the contrary in proportion as it is near the ceiling.

The loftier the windows, and the less their distance from

the ceiling, the more difficult is it to maintain the warmth of the room, and *vice versâ*. A large gap in the floor will frequently be found to occasion no loss of heat.

Attention should be paid, therefore, to the following points. 1. The joints and angles in wooden houses must be well made, and accurately fitted to each other. 2. The joinings in the roof throughout must be carefully stopped up. 3. The stove must shut well; that is, the plates must be fitted to the opening, without leaving any gaps. 4. There must be no aperture in the upper part of the window. 5. Nor in the upper part of the door. 6. It is best, therefore, to have double doors and windows. 7. Doors communicating with a cellar, or with the lower part of the house, admit a large quantity of cold air, and cause a draught in the adjoining rooms.

V. For the method of heating by stoves, and of maintaining the warmth for a very long time without much consumption of fuel, the reader is referred to our *New Construction of Stoves*.*

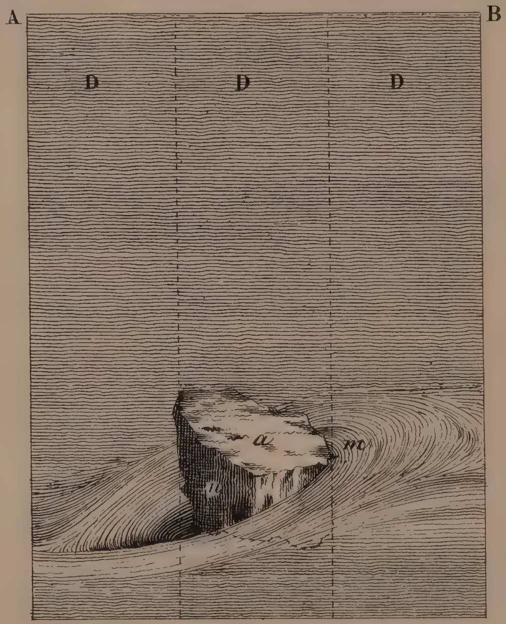
Liège, November 29th, 1721.

An Elucidation of a Law of Hydrostatics, demonstrating the Power of the deepest Waters of the Deluge, and their Action on the Rocks and other Substances at the bottom of their Bed.

In a former Treatise,† published in Swedish, I endeavoured to demonstrate from the laws of hydrostatics, that rocks of great bulk may have been torn from their places in the bed of the deepest waters of the deluge, and scattered over the land; as we find to be the case in the northern countries especially. But, to place the truth of this assertion in a clearer light, we shall now explain the rules to which we have alluded above.

* New Observations and Discoveries respecting Iron and Fire, and particularly respecting the Elemental Nature of Fire; together with a new Construction of Stoves, in *Some Specimens of a Work on the Principles of Chemistry*, p. 206, 8vo., London, 1847.

† *Om Wattnens Hoegd*, &c. (See note, p. 150.)


A
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Let AB be a vessel, or other receptacle, full of water; let *a* be a stone, or other massive body heavier than water, lying at its bottom, and let D be a column of water above it. It is well known, from hydrostatic principles, that, 1. The stone *a* is pressed on every side by the water. 2. This pressure is according to the height of the column of water. 3. According to this height, the stone is pressed in every direction, upwards, downwards, and laterally. 4. If the body *a* be set in motion, with a volume of the water; as for example, if it be a piece of timber, or the trunk of a tree, which exactly obeys the motion of the water, so that it is carried with the same velocity as the volume itself, it follows from thence, that the water nevertheless presses according to its height, both upwards and downwards, as well as towards the sides. The reason of this is clear; for the mass which obeys the motion of the volume of water, must be considered as in equilibrium, and its pressure by the water is the same, as if both itself and the water were at rest. 5. But here the reader will ask, whether the pressure of the water will be equal on every side of the stone, if the volume of water DDD be in motion, whilst the stone *a* is at rest at the bottom? Let the volume of water flow from *m* to *n*, whilst the mass *a* remains quiescent; we maintain, that in this case, there is a greater pressure on the above-mentioned mass *a* at the side *m*, than at the side *n;* for if the water flows from *m* towards *n*, the force of its pressure, together with the volume from *m*, decreases towards *n;* so that it is diminished in *n* as much as it is increased in *m*. We have ocular demonstration of this fact in every body of water in violent agitation; for if it strike against any quiescent object, as from *m* towards *n*, a sort of sinking of the water appears around *n*, or rather, it is like an empty space, which resembles either a hyperbolic or triangular cone. This is more evident in proportion as the force of the water is violent; when, therefore, we see that the water endeavours to escape from the part *n*, (since it is driven with rapidity, or requires time before it can return,) it is manifest that the pressure of the water must be diminished on the side *n*, whilst on the side *m* it remains, and is even increased. 6. Therefore, when the water is impelled against a heavy, quiescent body, it follows that the pressure or impulse will be in

proportion to the height of the column of water. For the water presses according to the height of the column; and as, in the example before us, this pressure exists on one side only, and not equally on the other, from which the water is striving to escape, the ratio of pressure is according to the height of the water.

From these data we have grounds for our opinion, that the stones and fragments of rocks in the bed of the waters of the Deluge might have been moved hither and thither with the water; and that after having been torn from their hills, they were carried into the plains; whence in some places the country is scattered over with them; in others ridges are formed, (of which a great number may be seen in Sweden,) and here and there the crust of the earth has been rendered uneven. This effect is also seen in dams, or water dykes, constructed of stones: if the height of the water is only a single ell, the stones remain in their places; but if it rises three or four ells, they are immediately torn from their site, and carried away by the stream. An effect of the same principle may also be seen in the smelting works, sometimes called *puchwerck,)* where the ores are beaten with hammers, and when pulverized, they pass into the lower canals, and we find that pieces of stone of no small size are carried for a considerable distance towards the lowest part of the canal, and frequently into the very pits. A similar result may be observed in the air, or at the bottom of our atmosphere, if the wind or volume of air strike against any plane surface, or if the latter be projected into the air, the force and resistance increase according to the velocity; all which effects may be considered as occasioned by the same causes. Many additional facts might be adduced in support of our position, should those already mentioned prove insufficient.

We have lately perused a little book published at Leipsic, under the title of *The History of Learning.** The authors, who are anonymous, have directed their pens against our *Miscellaneous Observations,* especially noticing the typographical errors, and objecting to the above-mentioned law of hydrostatics, as well as to our opinion respecting mathematical points;

* This *Historie der Gelehrsamkeit* has long since been consigned to oblivion.

on which subjects, God willing, we shall speak elsewhere. But in their preface, these writers tell us that they are anonymous, that they have no director, no chief, no law among them; that one contributor is not acquainted with another, and that nevertheless, without the assistance of inspiration, as they say, they bring forth a yearling volume under the above title. Who, or what they are, is no affair of ours: but, as they are anonymous, and without law or leader, in order without danger to themselves to lie in ambush for travellers, so we would have them know, that we consider it neither seemly nor advisable to challenge them to any sort of contest whatever*.

* From the *Acta Literaria Sveciæ*, vol. I., 1721, pp. 353—356.

THE END.

BIOGRAPHICAL NOTICES OF AUTHORS

MENTIONED IN THE PRECEDING OBSERVATIONS.

Boyle, Robert, born in 1626; died in 1691. (See *Principles of Chemistry*, p. 243.)

Bresmal, Jean François, a French physician, flourished towards the end of the seventeenth and beginning of the eighteenth century. The works to which Swedenborg alludes, are the "Hydro-Analyse des Minerales chaudes et froides de la Ville Imperiale d'Aix-la-Chapelle," &c., Liège, 1703, 12mo.; and "La Circulation des Eaux, ou l'Hydrographie des Minerales d'Aix et de Spa," Liège, 1719, 12mo. Both of these works are well written for the time in which the author lived.

Bromell, Magnus von, a learned Swede, born at Stockholm, 1679, died March 26, 1731. He studied medicine in Holland, France, and England, and was on terms of intimacy with the principal scientific men in each of those countries. On his return to Sweden, he was admitted a member of the Royal College of Physicians; and in 1710, he was intrusted with the arrangement of the sanitary regulations to be adopted against the plague which ravaged Stockholm and the whole of Sweden. He was afterwards appointed Professor of Anatomy in Stockholm, President of the Royal College of Physicians, and principal Physician to the King of Sweden. He collected a very excellent museum, consisting of coins, minerals, fossil remains, anatomical and pathological preparations, &c. A description of this museum is given in the *Acta Literaria Sveciæ* for 1736, p. 208. In his "Lithographia Svecana, Upsala, 1726," he mentions and confirms several of Swedenborg's geological researches. A German translation of this work was published in 1740.

Hauksbee, Francis, an English physician of the seventeenth century, celebrated for his researches in various branches of natural philosophy, especially on light and electricity. He published an account of his discoveries in his "Physico-Mechanical Experiments on various subjects; London, 1709," 4to. An edition in 8vo. also appeared in 1719.

Helwig, or Helwing, George Andreas, a mineralogist and botanist, born at Angerburg, in Prussia, in 1666; died in 1748. He delivered public lectures on his favourite sciences at Jena with great success: but afterwards he entered the church. The "Lithographia Angerburgica" was published in 1717—1720, at Kœnigsberg, in 2 vols., 4to., with numerous plates. He also published the "Flora Prussica," 4to., in 1712, with a supplement, in 1726; a treatise on Stones and Fossils, in 1717; and the "Flora Campana," 4to., with 12 plates, in 1719.

Hessel, or Hesselius, John, a Swedish physician and mineralogist: he accompanied Swedenborg in some of his travels. His researches on the mineral treasures of Sweden are very interesting, and are mentioned with great commendation in the "Acta Literaria Sveciæ," 1721, p. 184. He enriched the University of Upsala with numerous additions to its museum, and contributed several valuable papers to the Transactions of the Academy of Sciences of Stockholm, of which he was a member. He died in 1752.

A Melle, Jacob, a learned historian and numismatist, born at Lubeck in 1659, died in 1743. He travelled in England, France, and Holland, and corresponded with most of the learned in his times. On his return to Lubeck he entered the church. He published several works on history, numismatics, geological formations, fossil remains, &c. In his treatise, "De Lapidibus figuratis agri litorisque Lubicensis," published at Lubeck in 1720, 4to., he mentions Swedenborg's dissertation, "Om Wattnens Hoegd, &c.,"* in favourable terms.

Newton, Sir Isaac, born at Woolstrop, in Lincolnshire, Dec. 25th, 1642; died March 20th, 1727. His great work, the "Principia," was published in 1687, and the "Optics" in 1704.

Polhem, Christopher. (See *Principles of Chemistry*, page 244.)

Roberg, Laurence, a Swedish physician and mineralogist, born in 1664, died in 1742. He was appointed Professor of Medicine in the University of Upsala, and was a liberal contributor to its museum. He published his "Positiones Medicæ, Lugd. Bat. 1693," in 4to., "Grundvahl til plantekjænningn, Upsala, 1730," in 12mo., and several other works, in Latin and Swedish. He was likewise a contributor to the "Dædalus Hyperboreus."

Rudbeck, Olaus, a very learned Swede, was born at Westeras in Westmanland, in 1630, and died at Upsala in 1702. He was professor of anatomy and botany in the University of Upsala, and published several works on those sciences. The work to which Swedenborg alludes, is his "Atlantica, sive Manheim, vera Japheti posterorum sedes ac patria, Upsala, 1675-6," in four volumes folio, Swedish and Latin, with plates. It is a curious and learned work. His son, of the same name, was also distinguished for his learning, and published several works.

* See note, p. 150.

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